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Essays on the Determinants of Growth Rates Differences Among Economies:

Bringing Together Evolutionary and Post-Keynesien Growth Theories.

Essais sur les sources des différentiels de croissance entre économies:
Rapprocher les théories Post-Keynesiennes et Evolutionistes de la croissance.

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Résumé

Essais sur les sources des différentiels de croissance entre économies:

Rapprocher les théories Post-Keynesiennes et Evolutionnaire de la croissance.

Les facteurs expliquant la persistance de différences de taux de croissance entre économies est un sujet de recherche récurrent en sciences économiques, comme le montre le développement récent des “ Nouvelles Théories de la Croissance ” (NTC). Ce développement a eu pour conséquence d'éclipser des pans entiers de la littérature proposant des alternatives intéressantes dans la compréhension des facteurs de divergence entre économies ou régions.

Dans la lignée des travaux de J.A. Schumpeter, l'approche évolutionniste constitue l'une de ces alternatives. Elle développe une analyse du processus de croissance économique centrée sur le changement technologique. Les moteurs de la croissance s'y trouvent dans l'émergence et la diffusion de chocs technologiques, imprévisibles, par nature, à la fois en termes d'intensité et de fréquence. L'origine de ces chocs étant d'ordre micro-économique, les facteurs expliquant les différences de taux de croissance entre économies résident alors dans la capacité des économies à générer ou adopter ces changements technologiques. Une question se pose alors : Les seuls aspects technologiques peuvent-ils expliquer ces différences ?

L'approche post-keynesienne offre une seconde alternative au NTC. Si le changement technique y joue également un rôle central, ce dernier s'intègre dans une représentation plus complexe du processus de croissance, présentant ainsi une vision certainement plus subtile. Pour Kaldor (1966) la croissance économique est soutenue par un ensemble de mécanismes cumulatifs. Il parle alors de “ croissance cumulative ”. La croissance est ainsi tirée par la demande agrégée, elle même tirée par sa composante extérieure via un multiplicateur. La demande extérieure est fonction des revenus étrangers mais surtout de la compétitivité de l'économie domestique, cette dernière

dépendant de son avancement technologique. Ainsi le changement technique, lié à l'existence de rendements croissants, affecte la croissance au travers de la demande agrégée. Ces rendements croissants lient le changement technique à la croissance économique et donc à la demande agrégée. La combinaison de ces deux facteurs constitue le coeur de cette " croissance cumulative ". Il existe de ce fait un ensemble de retours macro-économiques affectant le changement technique et donc la croissance. Ces derniers constituent une part importante des facteurs expliquant les différences en terme de taux de croissance des économies.

Nous cherchons, au travers de cette thèse, à construire un cadre d'analyse basé sur les éléments proposés dans ces deux approches théoriques. Nous nous attachons, dans une première partie à mettre en évidence le caractère complémentaire de ces deux approches, facilitant de ce fait leur rapprochement. Ainsi, l'approche kaldorienne permet une représentation plus complète du cadre macro-économique, capturant ainsi certains effets des dynamiques macro-économiques sur le changement technique, approche que ne permet pas l'analyse schumpeterienne. Pour autant, l'analyse schumpeterienne apporte une compréhension microéconomique du processus de changement technologique, manquant à l'approche kaldorienne. C'est donc le rapprochement de ces deux approches qui permet une représentation plus complète du processus de croissance.

De plus, ce rapprochement est facilité par l'existence de certains points de convergence. En effet, post-keynesiens et schumpeteriens s'accordent sur l'importance du changement technique. Ils s'entendent également sur le fait que ce dernier est lié à l'existence ou l'émergence de rendements croissants.

Les deux courants se différencient dans la représentation formelle de ces rendements croissants. D'un côté, la " croissance cumulative " se base sur une représentation macro-économique agrégée, liant le taux de croissance de la productivité à celui du PIB. Cette relation est connue sous le nom de Loi de Kaldor-Verdoorn. Les schumpeteriens, de leur côté, considèrent ces rendements croissants comme émergeant des processus microéconomiques liés à l'apparition et à la diffusion de chocs technologiques. Les rendements sont alors par nature dynamiques.

L'existence de rendements croissants et une vision intrinsèquement dynamique des mécanismes économiques font que chacun de ces courants de pensée tend à rejeter l'analyse traditionnelle en termes d'équilibres. Le présent travail cherche à rester en phase avec cette vision, proposant une approche du processus de croissance " hors de l'équilibre ".

La seconde partie de notre thèse se concentre sur le changement technologique et l'existence de rendements croissants. Nous nous attachons dans cette partie à rapprocher les représentations, à priori divergentes, de ces composants clés du processus de croissance. Ainsi, après avoir vérifié la loi de Kaldor-Verdoorn au travers d'estimations empiriques, nous nous proposons de montrer qu'une telle loi constitue une propriété émergente d'un modèle microéconomique évolutionniste.

Cette loi permet d'identifier l'existence de rendements croissants au niveau agrégé. La simplicité de sa forme fonctionnelle évite l'abus d'hypothèses sur les caractéristiques et comportements microéconomiques. La loi de Kaldor-Verdoorn a été remise en cause, notamment du fait de l'émergence de nouveaux modes de production ou secteurs d'activité.

Nous proposons une estimation macro-économique de la loi, basée sur des estimations en coupes transversales de différents échantillons de pays, pour ces 50 dernières années. Ces estimations nous montrent que la loi de Kaldor-Verdoorn est vérifiée pour la majeure partie des échantillons. Mais ce résultat reste sensible au choix de l'échantillon utilisé. Notons que le seul échantillon pour lequel la loi ne se vérifie pas pour les deux dernières décennies est justement celui utilisé originellement par Kaldor.

Nous proposons ensuite d'estimer la loi au niveau sectoriel pour ces 20 dernières années en nous basant toujours sur une analyse en coupe transversale. Ces estimations nous permettent de conclure que la loi de Kaldor-Verdoorn est également vérifiée au niveau sectoriel et ce pour la plupart des secteurs, y compris ceux apparus après les années 70. Ce résultat paraît en contradiction avec l'analyse de Kaldor (1966) pour qui l'existence de rendements croissants est un caractère propre aux seuls secteurs manufacturiers.

Ainsi vérifiée au travers de ces estimations, la loi de Kaldor-Verdoorn met en évidence l'existence de rendements croissants tant aux niveaux macroéconomiques que sectoriels. Elle n'offre néanmoins aucune indication sur les sources de ces rendements croissants. Pour mettre en lumière certaines de ces sources, nous avons recours à un modèle microéconomique basé sur une modélisation évolutionniste du changement technologique. Ce dernier se base sur une population de firmes hétérogènes dont la rationalité se limite à l'application de règles de décisions prédéfinies. Ces firmes sont sujettes à de possibles mutations dans leurs caractéristiques technologiques. Ces mutations sont endogènes et liées aux investissements en capital et en R&D des firmes. Ce modèle fait alors l'objet d'une série de simulations. A partir de ces dernières, nous avons pu mettre en évidence l'émergence d'une relation de type Kaldor-Verdoorn semble au niveau agrégé, confirmant l'existence de rendements croissants. De plus, nous avons pu constater l'influence non négligeable de certaines caractéristiques micro-économiques sur la valeur des coefficients de la loi telle qu'estimées à partir des simulations : plus les chocs technologiques sont fréquents, favorisés en cela par les investissements en R&D, plus le coefficient de la loi de Kaldor-Verdoorn est important et significatif. Enfin, plus l'amplitude de ces chocs est importante, plus les rendements d'échelle, mesuré au travers du coefficient de Verdoorn sont importants; mais ces derniers sont de moins en moins significatifs.

Dans la troisième partie de la thèse, nous cherchons à transposer les éléments complémentaires des deux approches dans des modèles macro-économiques. Les modèles développés se basent sur une modélisation évolutionniste du changement technique telle que décrite précédemment. Ces processus sont ensuite intégrés dans un cadre macro-économique inspiré par les modèles de "croissance cumulative". Les composants macro-économiques des modèles agissent comme des contraintes sur les processus micro-économiques liés au changement technologique, ces contraintes macro-économiques étant elles mêmes affectées par ces processus microéconomiques. Ainsi ces modèles ajoutent au cadre évolutionniste un ensemble de retours des niveaux macro à micro mais également micro à macro. Ce cadre d'analyse sera développé au travers de trois modèles :

Le premier est un modèle composé d'un unique secteur de production. Ce modèle sert de base aux modèles développés dans les chapitres suivants. Le cadre macro-économique s'inspire des travaux de modélisation de la "croissance cumulative" de Dixon et Thirlwall (1975) ou Thirlwall (1979). La demande agrégée, fonction des exportations, y est déduite de la balance des paiements. Les simulations mettent en évidence l'émergence de régimes de divergence distincts. Dans un de ces régimes, les divergences sont dues aux chocs technologiques, mais n'ont qu'un effet transitoire. Cet effet peut, pour certaines spécifications des mécanismes de liaison micro-macro, conduire à la disparition des économies les plus faibles. Le dernier régime se caractérise par une persistance des différences de taux de croissance directement liée aux caractéristiques de la demande.

Un second modèle ajoute une dimension multi-sectorielle à notre analyse; la modélisation des contraintes macro-économique suivant un schéma similaire au modèle précédent. Ce modèle nous permet de mettre en parallèle les facteurs liés au processus de spécialisation sectorielle et la persistance de différences de taux de croissance entre économies. Deux régimes de spécialisation émergent de ces simulations. Le premier est lié aux différences technologiques micro-économiques et aux mécanismes de liaisons micro-macro. Dans ce cas la compétition internationale conduit les économies à se spécialiser dans les secteurs les plus compétitifs. Dans l'autre régime, la structure sectorielle des économies est directement dictée par les caractéristiques de la demande. C'est alors la spécialisation qui conduit à l'apparition de différences en taux de croissance. Ces différences ne sont que transitoires s'il n'existe pas de différences significatives au niveau des demandes sectorielles. Dans le cas contraire, ces différences persistent dans le temps.

Dans le troisième modèle, nous relâchons la contrainte liée à la balance des paiements, mais introduisons, du côté des demandes sectorielles, des niveaux de satiété et un certain degré d'interdépendance intersectorielle. Ces modifications ont pour effet de relativiser certains résultats du modèle précédent. Ainsi, dès lors que les niveaux de satiété sont atteints, les effets de la structure de la demande sur la spécialisation et les différences de taux de croissance s'estompent. Seul un changement structurel constant, consécutif à des chocs au niveau de la structure de la demande, permet de retrouver cette persistance des différences en taux de croissance.

Un résultat important se dégage de ces trois modèles : les contraintes macro-économiques ont une influence cruciale sur l'émergence de différences en matière de taux de croissance. Ce sont des canaux liés aux contraintes macro-économiques qui permettent aux chocs technologiques d'affecter la dynamique macro-économique dans son ensemble. Ces chocs sont eux même affectés par cette dynamique macro-économique grâce aux effets de retour du niveau macro vers le niveau micro engendrés par ces contraintes.

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Part I

Facts and Thoughts on Economic Growth: Some Introductory Considerations

Chapter 1

Why do growth rates differ among economies? An Introduction

The empirical stylised fact that countries rarely grow at the same rate is unanimously accepted in the economic analysis. These differences even tend to persist over time (Kaldor 1957), not only between advanced and developing countries. Despite a tendency towards converging growth rates at the aggregate level among the most advanced economies, in Europe for example, evidences of patterns of divergence can be found at the regional level (Fagerberg and Verspagen (1996). Economic growth is uneven by nature.

The empirical evidences has highlighted the endogenous nature of the economic growth process. As a matter of fact, economic growth seems to be largely affected by the actions of the various economic agents at various economic levels (Dosi, Freeman and Fabiani (1994), Verspagen (2000)). Economic growth is therefore also an endogenous process.

Empirical evidences also show that the persistence of the differences in growth rates across economies are usually related to the differences in the ability of the economies to sustain economic growth, and/or to develop the necessary competences to catch-up with the leading economies (Dosi and Castaldi (2002), Castaldi and Dosi (2003), Fagerberg and Verspagen (2001). Economic growth is therefore a persistently uneven and endogenous process.

The aim of this thesis is to provide some theoretical explanation to the persistence of growth rates differences across economies.

Understanding growth rates differences among economies necessarily requires the understanding of the growth process itself. This is an age-old issue in economics. Reverting to the classics, economic growth has been considered as an endogenous process driven by the changes in the production capacities of the economies. Two major viewpoints emerged from the classical literature. First the Smith/Young approach highlights the key role played by increasing returns. These rely on the increasing specialisation, led by the processes of division of labour, both at the micro- and the macro-economic level. Second, the Marx/Schumpeter approach considers technological change as the main driving force sustaining long-run waves of economic growth.

Contemporary theories are traditionally considered to start with the Harrod (1939, 1946) and Domar (1946) analysis. This latter approaches the analysis of long-run growth following Keynes' (1936) short run analysis. Within this so-called Harrod-Domar framework, a dichotomy between demand and technology related growth's engines generates the instability of the long-run growth path.

On the demand side, the 'warranted rate of growth' defines the rate at which productive capital is accumulated. The latter depends on the combination of a multiplier effect on savings and an accelerator effect on investments; both are directly inspired by the short-run Keynesian macro-economics.

On the technological side, the 'natural rate of growth' defines the rate at which the production capacity grows. The natural rate of growth is a function of the exogenous rates of growth of population and of labour productivity.

The 'warranted' and 'natural' rates of growth are independent, and therefore unlikely to be the same. If the warranted rate of growth is lower than the natural one, the economy grows at the same rate as the one of capital accumulation, leading to an under-use of the labour factor (i.e. long-run unemployment). On the contrary if the economy grows at the natural rate of growth , lower than the warranted one, there is full employment but with under-use of capital. The only balanced growth path corresponds to the 'knife-edge' situation where the two rates of growth are equal and therefore all the production factors are fully employed.

Solow (1956) solves the instability of long-run growth found in the Harrod-Domar framework, by introducing some degrees of substitution between production factors. The unique balanced growth path is then defined by the sum of the population's rate of growth and of technical change. In other words, growth is driven by something similar to the 'natural rate of growth'. Each economy converges necessarily towards this exogenously determined rate of growth. If differences in growth rates among economies do occur, these are only due to their initial conditions, i.e. to their relative position with respect to the exogenous rate of growth. Solow solves therefore the problem of the instability of growth allowing for factor substitution and for the 'natural rate of growth' to prevail. This latter is however entirely defined by non-economic factors.

The 'New Growth Theory' (NGT) which developed from the mid-1980s onwards, aimed to endogenising the factors underlying economic growth. The main answer provided by the NGT was to bring some economic justification to the existence of non-decreasing returns. These latter insure the endogenous nature of the growth process. A first wave of NGT models simply assumed the existence of increasing returns. These latter were founded on the existence of positive externalities due respectively to: (i) the accumulation of knowledge through learning-by-doing (Romer (1986)); (ii) the accumulation of human capital (Lucas (1988)); (iii) the externalities produced by the public expenditures in tangible or intangible public goods (Barro (1990)).

The second wave of models follows the contribution by Romer (1990), Grossman and Helpmann (1991) and Aghion and Howitt (1992). These models provide a micro-founded justification to the existence of increasing returns. According to Romer (1990), increasing returns are due to the accumulation of new intermediate good sectors, emerging from an explicit R&D process. Romer (1990) presents therefore a 'Neo-classically' micro-founded interpretation of Young's concept of (1928) macro-level division of labour. Grossman and Helpmann (1991) and Aghion and Howitt (1991) propose a dynamic justification to increasing returns. These latter are rooted in the increasing in the quality level of the intermediate goods. The mechanisms underlying this improvement result from a 'creative-destruction' process driven by R&D activity. These models present a Neo-classical re-interpretation of the Schumpeter/Marx analysis.

In all these cases, the differences in growth rates among economies are linked to the amplitude of the externalities. This latter is in turn related to the size of the economies: the larger the economy, the higher the growth rate. This argument holds only when the economies are closed to foreign trade. If the economies are open, externalities tend to diffuse among economies. As showed by Grossmann and Helpmann (1991), in open economies either all the economies converge to the same rate of growth, or the lagging economies to disappear. There is no intermediate situation. The most recent developments of the NGT have integrated more complex representations of the aggregate production function or the consumption function. Differences in growth rates are then justified by the existence of multiple equilibria. Despite the increasing complexity in the representation of growth mechanisms within NGT developments, the persistence in the differences in long-run growth are deterministically linked to the initial conditions, as in the Solow model.

Over the years and the growing sophistication of the model, the mainstream growth theory tend to overlook rather than solve the original dichotomy in the growth mechanisms originally stressed within the Harrod-Domar framework. NGT has basically assumed the existence of the Say's Law. This has led the demand component to be simply ignored in the analysis, as stressed by Thirlwall (2003):

> "NGT lies squarely in the orthodox neoclassical camp in which growth is driven from the supply side. Saving leads to investment, a country's balance of payments looks after itself, and countries converge on their own natural rate of growth which is not itself explicitly dependent on the strength of demand within an economy [...] To assume that Say's Law of Markets holds is just not good enough"

With supply's growth path driving all the growth process, the attention is all focused on the technological components of the growth mechanisms: first as an exogenous component, and later as an outcome of the R&D investments decisions. For the New Growth Theory technology is the only factor sustaining growth by generating increasing returns. The focus on these increasing returns is such that, as pointed out by Boyer and Juillard (1992), the NGT might even tend to present *"too many contradictory explanation for a single phenomenon"*.

Prior to the NGT, the idea that increasing returns are a source of growth goes back to the classical growth theories. Young (1928) developed the idea that the existence of increasing returns not only generates growth but also insures that growth is a self-sustained process. For Young (1928), increasing returns are not limited to the micro-economic level and the large-scale unit of production but emerge at the macro-economic level due to the macro-division of labour, which generates new markets and extends the existing ones. These latter are therefore not supply-driven but demand-driven. The emergence of new markets via the emergence of new intermediate goods is at the heart of Romer's model of increasing returns. However, this demand-driven factor is passively affecting growth, due to the systematic use of the Say's law. In other words the NGT develops around a very narrow re-appropriation of the classical growth theories.

After five decades of development of the mainstream growth theories, what we actually know about growth mechanisms can be summarised as follows: First, the main source of growth relies in the existence of increasing returns. Second, if growth rates differentials exist, these are deterministically determined by differences in the initial conditions and especially the size of the economies. In this sense, the NGT might provide a poor explanation for the growth rates differential, based on the misinterpretation of prevailing theories, as pointed out by Fine (2002). Further, NGT overlooks a long tradition of heterodox growth analysis drawn upon the same classical theories.

We will not propose here another critical view of the NGT. We will rather revert to the initial Harrod-Domar dual representation of the growth mechanisms (i.e. demand vs. technology). The aim of this work is to go beyond the dichotomy of the Harrod-Domar framework and provide an approach of the growth mechanisms based on the co-evolution of technological developments and the expansion of demand. In this sense, growth rates differences among economies ought to be linked not only to the differences in technological factors, nor to the demand factors but also to the channels through which these two interact.

Chapter 2, presents an alternative approach to the NGT theories that represents the theoretical background of our thesis. This chapter is followed by a detailed outline of the different points developed along the thesis.

Chapter 2

Alternative Theorising on Economic Growth

In the introduction we recalled the recent developments in the mainstream growth theory, and we came to the conclusion that the 'Harrod-Domar' dichotomy explaining growth mechanisms has not be solved yet. In its more recent developments the New Growth Theory give a central role to increasing returns. These latter rely on technological change as well as in the extension of the markets. This latter source of increasing returns corresponds exactly to the demand counterpart of the Harrod-Domar framework. In other words, the mainstream growth theories seems to be back to its starting point.

This might leave open the possibility to explore another route and to propose an alternative approach to endogenous growth processes. Our aim along this thesis is to propose such an approach to highlight the sources of growth differentials among economies. To revert to the problem posed by the Harrod-Domar approach, such a framework tackles simultaneously the demand and technological sources of the growth process and their interactions in explaining growth. In this sense, our proposed framework captures the micro-effects of technological dynamics on the macro-level as well as the macro-to-micro feedback mechanisms.

This chapter reviews the theoretical foundations which we build upon to provide our alternative framework. The development of the New Growth Theory tend to overlook a whole stream of literature which dates to the first half of the 20th century. Among these alternative approaches, we examine two of them. These are, first, the Post-Keynesian or Kaldorian approach to economic growth also known as Cumulative Causation growth theory, and second the Neo-Schumpeterian or Evolutionary theory, which dates back from the seminal work of Nelson and Winter (1982). On the one hand, the Kaldorians, including Kaldor himself, consider growth as a self-reinforcing process linked to the strong interconnections between macro-dynamics and technological dynamics. On the other hand, the evolutionary approach allows to account for technological dynamics, their micro-foundations and their effect on macro-dynamics. As we argue later in this chapter, even if these two approaches only propose partial analysis of the interactions between macro-dynamics and technological change, they nevertheless seem to complete each other providing room for building an integrated framework.

The chapter is organised as follows : Section 2.1 is devoted to the review of Kaldor's work on growth and the formal developments of cumulative causation theory. Section 2.2 focuses on the foundations on Evolutionary theory and the recent development in evolutionary modelling of economic growth. The last section (2.3) is devoted to the discussion of the complementarities among these two approaches, the possible connections for providing a more complete framework.

2.1 A Macro-approach to Growth and Technical Change

2.1.1 N. Kaldor: Towards 'cumulative causation' growth

The scope of issues considered by N. Kaldor along his career covered a wide range of economic questions, from imperfect competition to monetary macro-economics. Here we concentrate on his contribution to the theory of economic growth. If Kaldor' s influence on the latter is undeniable, his contributions were scattered along his diverse works without, as he acknowledged himself, ever fully elaborate a 'general theory' based on his diverse contributions.

For the scope of this survey, we can point three major statements to be found in Kaldor' s work on economic growth:

First, economic growth is an historical process. In this respect Kaldor reported a set of empirical regularities (i.e.'stylised facts') concerning long-run growth. Second, the undeniable influence of technical change and increasing returns on growth have to be considered as endogenous processes. Finally, he considered aggregate demand as necessary to ensure a self-sustainable growth process.

These three components of Kaldor's growth analysis are the basis for the development of his 'cumulative causation' approach to economic growth, as we detail in the next section.

Introducing his 1957 growth model, Kaldor clearly pointed out the importance of modelling and understanding the process of economic growth as an historical process:

> "A satisfactory model concerning the nature of the growth process in a capitalist economy must also account for the remarkable historical constancies revealed by recent empirical investigations." Kaldor (1957)[1]

In this respect, he underlines the following set of statistical regularities, or stylised facts, characterising the histroy of economic growth in capitalist economies :

- Industrialised economies face continuous growth in GDP and continuous increase in labour productivity.
- Industrialised economies face continuous increase in the ratio capital per workers.
- Profits rates on capital are regular.
- Ratio capital over GDP is constant and regular over periods.
- Income distribution is constant over time. The share of labour income over GDP is constant over time, this implies that the wage growth rate will be proportional on average to productivity increases.
- There exist non-negligible differences among economies in growth rates of GDP and of labour productivity increases.

This set of stylised facts were probably the most influential contribution of N. Kaldor to the analysis of economic growth, cited by most of growth theorists, from the 'New Growth Theorists' to 'Evolutionary economists', including obviously his direct followers.

For Kaldor these facts challenge directly the Neo-classical approach to economic growth, and the use of a traditional production function. He stresses the need to consider technical change as an economically driven process (see Kaldor (1957)). He then considers technical change as driven by investments, and the renewing the production capabilities, rejecting at the same time the concept of 'stock of capital' in favour of a more disaggregate conception of production capabilities (closer to the idea of capital vintages).

[1] p. 260, as reprinted in 'Essays on Economic Stability and Growth'

The accumulation of newer, and therefore more productive machinery, implies gains in labour productivity. In this respect he introduces the concept of *'technical progress function'* (Kaldor (1957), Kaldor and Mirrlees (1962)). The latter links the rate of growth of labour productivity to that of capital per worker (i.e. investment in capital goods) in an increasing but concave function.

In the mid-sixties, starting from his Inaugural Lecture in Cambridge (1966), Kaldor's increasing interest towards applied economic growth led him to modifies his conceptualisation of technical change. Namely he went beyond the 'technical progress function', to capture the effect of technical change on growth. From the mid-sixties on, in Kaldor' s view, technical change, at the heart of the growth process, is directly linked to the existence of increasing returns. These latter can be static and/or dynamic (Kaldor (1966,1972)). As static increasing returns, one has to understand the 'classic' concept of increasing returns to scale, mainly at the firm level. They emerge in large scale production systems due to labour specialisation and learning-by-doing.[2] Dynamic increasing returns are the combination of two distinct processes. The first one is directly linked to the 'technical progress function'. It implies that the resources generated are invested in production capacities, allowing for larger production scales, but also more efficient ones due to the accumulation of more recent generations of machinery. The second effect refers directly to Young (1928), and relies on a macro-level extension of the idea of division of labour to be found in the Classics analysis . According to Young the existence of a macro-level division of labour generates a self-sustaining economic growth process. In this respect, dynamic increasing returns occur at the macro (or meso) level. For Kaldor, these increasing returns are the main engine for productivity increasing, but remain mainly confined to the manufacturing sectors. This leads him to present the manufacturing sector as the main engine for growth (Kaldor (1966)), and competitive advantage in international trades (Kaldor (1981)).

The formalisation chosen to represent these increasing returns effects refers directly to the work of Verdoorn. The equation is nowadays known as the Kaldor-Verdoorn Law. It linearly links the productivity growth rate to the growth rate of output via the Verdoorn coefficient, plus a constant term. This equation will be at the heart of the cumulative causation growth models.

Moreover, the undeniable role of increasing returns in generating a sus-

[2] Note that the latter will constitute one of foundations of the NGT, but twenty years later.

tained growth in production capacities of the economies is not sufficient for N. Kaldor to explain growth processes. In this respect, he considers, Young (1928) or Myrdal (1957) analysis as incomplete. He stresses the necessity to consider the demand factor in the analysis of economic growth[3]. Demand provides the missing link between increases of production capacities due to increasing returns and the generation of income growth.

Demand induces a 'chain reaction' along the economy. The rate at which industries grow is related to the rate at which the others grow. Dynamic industries generate income, then demand spreads across the entire economy:

> "[T]he increase in demand for any commodities [...] reflects the increasing in supply of other commodities, and vice versa " (Kaldor (1966) p.19)

The nature of this 'chain reaction' is rooted in the demand structure of the economy. The demand structure relates to three distinct but interrelated components: Internal consumption, capital investment and external demand.

First the internal demand structure is defined by the "changes in the consumption structure associated with the rise in real incomes per head" (Kaldor (1966), p.19). This is linked to the income elasticities of each sector's demand. The latter directly influences the distribution of growth impulses within the economy:

> "The chain reaction is likely to be more rapid the more the demand increases are focused on commodities which have a large supply response [i.e. increasing returns], and the larger demand response induced by increase in production." (Kaldor (1966) p.19)

Income elasticities are directly connected to the social structure of the economy. Hence Kaldor (1966) distinguishes three income classes affecting the nature of income elasticities:

- Low-income classes, which mainly consume food and primary goods.
- High-income classes whose consumption is rather concentrated on services.
- A middle-income class whose consumption is concentrated on manufactured goods.

The value of income elasticities at the aggregate level depends on the relative importance of these groups in the economy. The higher the income elasticity,

[3]See Kaldor (1966, 1970, 1972).

the more efficient the 'chain reaction', therefore economic growth mechanisms rely on mostly on this middle income group.

The second component of demand dynamics is represented by capital investment. It concerns the industrial sectors. This component explains how demand dynamics allow growth impulses to diffuse across the economy, depending on the properties of production technologies in each industries, and the cross sectoral linkages. The rate of growth of products demand triggers investment expansion. Investments affect economic growth through two distinct channels, first as exposed above by providing dynamic increasing returns (i.e. the renewing of production capacities) and second by constituting an outlet for the industrial sectors.

External demand is the last component of aggregate demand. For Kaldor, to sustain growth, economies have to reach the stage in which they become 'net-exporter' of manufactured consumer and capital goods. In advanced stages of development, self-sustained growth relies on the combination of growth impulses linked to external demand with the self-generated growth of domestic demand:

> "both rate of growth of induced investments and the rate of growth of consumption become attuned to the rate of growth of the autonomous component of demand, so that [the latter] will govern the rate of growth of the economy as a whole." (Kaldor (1970))[4]

For Kaldor the whole growth process is in turn driven by this autonomous component of demand, function of the world income growth.

2.1.2 Cumulative Causation: From Thoughts to Models

From his diverse contributions Kaldor derives what he calls 'the principles of cumulative causation', according to which economic growth is a self-reinforcing phenomenon generating the necessary resources to sustain itself over the long-run. The cumulative nature of the growth process relies on a circular conception of the growth process and the co-evolution of two major dynamics: increasing returns and increasing aggregate demand.

Dynamic increasing returns ensure the long run growth of production capacities. These increasing returns are directly related to technical change. Technical change is itself generated within the economic system, through investments and division of labour[5].

[4] As quoted by Boyer and Petit (1991)

[5] In this respect N. Kaldor recognized almost two decades before what will become the driving forces of growth for the New Growth Theory

Following the Keynesian tradition, Kaldor considers economic growth as a demand driven process. Increases in aggregate demand will drive economic growth absorbing the increases in production capacities. Increases in the autonomous component of aggregate demand (i.e. exports) leads to a ' multiplied' increase of output and thus income (Kaldor (1966,1981)). This stresses at the same time the importance of international trade for growth.

These two main dynamics are interrelated. In generating income, aggregate demand dynamics create the resources to sustain investment and then sustain dynamic increasing returns. This effect is synthesised by the Kaldor-Verdoorn Law. Second, dynamic increasing returns sustain the competitiveness of the economy on international markets. This latter fosters exports and therefore sustains aggregate demand dynamics *via* the multiplier effect. These two cumulative causation then makes that economic growth is a circular and self-reinforcing process.

This cumulative vision of the growth process leads Kaldor to consider two possible growth path:

- Growing through a 'virtuous circle' : The multiplier effect ensure that gains in productivity are sufficient to sustain competitiveness and therefore aggregate demand, on the one hand. Dynamic increasing returns, on the other hand, ensure that aggregate demand provides the necessary resources allowing to sustain dynamic increasing returns.

- Drowning in a 'vicious circle' : Dynamic increasing returns are not sufficient to sustain competitiveness and/or the multiplier effect does not allow demand to sufficiently sustain dynamic increasing returns.

The structural characteristics of the economies (i.e. among others, industrial specialisation) defines the ability to enter in a virtuous circle. These two growth schemes, and the cumulative nature of the growth process recalls the grip of history and the undeniable historical nature of growth analysis. It offers theoretical foundations to the existence of continuous, but significantly different, GDP and labour productivity growth rates among industrialised economies as reported in the 1957 paper' s set of stylised facts.

Dixon and Thirlwall (1975) present one of the first attempt to formalise Kaldor's analysis. Following Kaldor's decriptive account of the cumulative mechanisms underlying economic growth, they develop a simple model of regional growth.

Following the Keynesian tradition, GDP is represented by aggregate demand. Its growth rate (y_t) is a linear function of the exports growth rate

(x_t) through a multiplier[6]. The latter is directly inspired by Hick's 'super-multiplier' principle.

$$y_t = \varepsilon x_t$$

Exports represent here the only 'autonomous' component of aggregate demand. The growth rate of exports is linearly linked to foreign income growth rate (y_t^*) by income elasticity on the one hand. The latter is considered by the authors as a proxy for non-price competitiveness. This argument represents the degree of specialisation or of integration of the economy in world trades. On the other hand exports growth rate is linearly related to the growth rate differential between domestic (p_t) and 'world average' prices (p_t^*) by price elasticity. This second component captures the effect of price competitiveness dynamics on the dynamics of external demand.

$$x_t = \alpha y_t^* + \beta \left(p_t^* - p_t\right)$$

Domestic prices are set applying a mark-up on unitary production costs. Price dynamics are then determined by the difference between an exogenous wage growth rate (w_t) and an 'endogenously' defined labour productivity growth rate (a_t).

$$p_t = w_t - a_t$$

Note that Dixon and Thirlwall made the implicit assumption that labour supply perfectly respond to labour demand itself driven by growth.

Technical progress implies labour productivity growth rate (a_t). It is formally represented by the so-called 'Kaldor-Verdoorn Law'. Hence increase in productivity will be function of economic growth (y_t).

$$a_t = \lambda y_t + \epsilon$$

The model as defined by Dixon and Thirlwall (1975), is compatible with the stylised facts concerning the structure of income distribution among production factors, capital intensity and profit rates on capital. It generates continuous growth rates in GDP and labour productivity. It is also easy to show with this model that for some values of the structural parameters the economy enters into a virtuous growth circle, while falling in a vicious growth circle for some other values.

In its 1979 paper, Thirwall introduces in this framework an explicit balance of payment constraint.[7] To achieve this, the authors introduce an explicit formulation for imports dynamics, modelled on exports dynamics as in Dixon and Thirlwall (1975), and exchange rate dynamics.

[6] Equations are ours. They aim at clarifying the argument and do not intend to reproduce exactly the model by Dixon and Thirlwall (1975).

[7] See Thirwall (1979) and Mc Combie and Thirlwall (1994).

The import growth function, jointly with the introduction of a balance of payment constraint leads to the formalisation of a trade multiplier in the Harrodian tradition. The latter is computed as the ratio between income elasticities to external demand and to internal demand for foreign goods. Hence the structure of demand directly influences growth dynamics. The exchange rates dynamics absorbs partially competitiveness differences. These exchange rates dynamics, also neutralises the effect of decreases in wages to accelerate growth through external demand channels linked to price competitiveness (See Mc Combie and Thirlwall (1994)). Introducing this constraint tends to limit growth rate differentials but does not eliminate them.

Amable (1992) develops the non price competitiveness dimension of demand dynamics in the balance of payment constrained cumulative causation framework. Imports and exports dynamics representations become also linearly dependant on the 'quality' competitiveness of the economy. Quality increases through a learning by doing process, function of the accumulation rate of GDP. This specification reinforces at the same time the cumulative nature of the growth process and its path dependency.

2.2 Evolutionary Theorising on Economic Growth:

2.2.1 Evolutionary Thinking and the Work of Nelson and Winter.

The Evolutionary approach to economic change develops around Nelson and Winter work. Their book, "Evolutionary Theory of Economic Change", published in 1982, is considered as the foundation of modern evolutionary theorising on the economic analysis of technical change. Part IV of their book concerns directly the analysis of economic growth. It has provided the foundations of the evolutionary modelling approach of economic growth.

Evolutionary theory is in the direct line of Schumpeter writings on long run economic development. It gives a central position to technological change, whether radical or incremental, due to the single entrepreneur or to institutionalised R&D activity. Moreover, evolutionary theory places the source of technical change at the firm level; in their investment behaviours, and their learning capacities.

Following Schumpeter 's idea, economic systems evolve out-of-equilibrium. The existence of turbulence led by technical change cannot be understood in an equilibrium framework; as quoted by Andersen (1994):

> “[T]here was a source of energy within the economic system which would of itself disrupt any equilibrium that might be attained.”

This source of energy is technical change. Thus evolutionary modelling does not assume a priori the existence of an equilibrium. If it exists, it has to emerge from economic dynamics.

Moreover, evolutionary theory substitutes population dynamics to the representative agent assumption. These population of agents are heterogeneous, and evolve in highly uncertain environments. This uncertainty is due to the imperfection of information and of the perception of the technology dynamics of an intrinsically uneven nature. This uncertainties are incompatible with the substantial rationality found in mainstream economics. Evolutionary economics therefore naturally assume that agents are bounded rational. The behaviours are then confined to the application of decision routine such as fixed or adaptive decision rules. The uncertain nature of the world and the limitation of the rationality of the agents brought evolutionary economics towards an ‘out-of-equilibrium’ analysis focusing on dynamics processes rather than on the existence of equilibrium.

From the modelling perspective, evolutionary economics directly refers to its namesake in natural sciences. The dynamics of economic systems rest on three major characteristics:

- *Heterogeneity:* Economic agents can differ in their characteristics (i.e. in term of behaviour, history, learning capacity among others) similarly to the genetic characteristics in natural sciences.

- *Mutation:* Agents characteristics can be subject to evolution. This mechanism of mutation may concern behavioural patterns, or technological patterns among others.

- *Selection:* This process allows to differentiate between heterogeneous agents. It defines survival or extinction of agents on the basis of given characteristics (i.e. competitiveness, profitability and so on...)

These three features governing evolutionary dynamics are strongly interrelated. The selection process could only occur in a heterogeneous environment. The selection process, however, tends to limit heterogeneity. To survive the selection process, heterogeneous agents have to mutate. The continuous mutations in the populations characteristics insure the persistence of selection process. An evolutionary modelling cannot therefore be considered without these interrelated processes.

Further, Evolutionary growth models all aim to reproduce historical growth patterns. As stated by Nelson and Winter (1982):

> "The challenge to an evolutionary formulation [is to] provide an analysis that at least comes close to matching the power of the neoclassical theory to predict and illuminate the macro-economic patterns of growth". (Nelson and Winter (1982) p. 206)

Evolutionary growth modelling does not attempt to represent a balanced or stable growth path, but aims to reproduce a set of regularities and facts to be observed and emerging from the long-run growth patterns found along history.[8] The seminal work by Nelson and Winter (1982) explicitly aims to reproduce and explain Solow (1957) data on total factor productivity for the United States. Their main target is to model growth process in an evolutionary way, generating "*considerable diversity of behaviour at the level of firm*" as well as an "[...]*aggregative time path of certain variables* [...]", staying consistent with history but also compatible with Solow's results.

To sum up, we can briefly sketch Nelson and Winter (1982) growth model as follows :

First, heterogeneity is considered at the firms level. Each firm is characterised by its own production process (which can differ from others). Firms produce using a Leontiev type of production function. This excludes any substitution between capital and labour for a given technology. Firms exhibit constant returns to scale in the short-run. Increasing returns emerge from technology dynamics. Technologies (i.e. production factors' productivity levels) are drawn from a given and finite 'pool of existing techniques'. The latter represents the state of advancement in scientific and technical knowledge. At any point in time, only some of the production techniques are known and used, while other remain to be discovered.

Second, selection occurs through market mechanisms. At each period, aggregate demand (assumed exogenous) and aggregate supply (defined by firms production capacities) clear the market for homogeneous goods. At each period, market clearing defines the price level. The latter, combined to wage level, technological parameters and capital stock, defines each firms' profitability level. When firms' profitability level is below a given threshold, they exit the market.

Finally, mutation concerns here the changes in technological characteristics (i.e. the production function parameters). Mutation corresponds to technical progress as a result from a formal R&D activity. This latter is of two distinct types :

- 'Local search' consists in the development of unused and undiscovered

[8] Evolutionary growth models being, in fact, the outcome of a large empirical literature developed often by the same scholars. Even if we choose not to review this literature here, this fact deserves to be stressed.

sets of techniques within the pool. The local nature of this process resides in the concentration of the probability distribution of the possible new techniques around the existing ones. This reflects in a way the increasing cost of changing existing routines to adopt more distant techniques.

- 'Imitation' consists in the adoption of other firms techniques. The probability of success in imitating is proportional to the spread of a given technology in the economy.

The entire macro-economic dynamics is resulting from the micro-dynamics of competition and technical change. Formally, Nelson and Winter (1982) consider economic growth as driven at the micro-level.

2.2.2 Evolutionary Modelling of Economic Growth.

Nelson and Winter (1982) contribution has been follwed by an entire branch of evolutionary economics devoted to the formal modelling of the economic growth process. However, the seminal quality of their work did not prevent this literature from being highly heterogeneous. The core of the evolutionary principles, such as heterogeneity, selection and mutation processes or assumptions as the bounded rationality or the key role played by technological changes remain common characteristics of these models. Their formal representation of the growth mechanisms nevertheless differ among approaches. These approaches can be grouped into three main trajectories.

A first trajectory emerged with the works by Chiaromonte and Dosi (1993), Dosi and Fabiani (1994) and Dosi, Fabiani, Aversi and Meacci (1994). These models share with Nelson and Winter (1982) a disembodied conception of technical change, that distinguishes them from other evolutionary growth models. The production process is represented by a Leontiev production function. Chiaromonte and Dosi (1993) consider a two sector model with a capital good sector and a consumption good sector. The capital good is used in the production process of the consumption good. While in Dosi and Fabiani (1994) and Dosi, Fabiani, Aversi and Meacci (1994), labour represents the only production factor.

Heterogeneity is considered at the firm level, representing the most disaggregated level of analysis of these models. It concerns both firms technological capacities (i.e. productivity levels) and firms' behaviours. Hence firms might differ in terms of technological strategies, by allocating resources (i.e. profits) to R&D activity (innovation or imitation), and in terms of market strategies, the mark-up pricing rule being function of 'market share targets' by firms (in Chiaromonte and Dosi (1993) and Dosi et al. (1994)) or using a fixed parameter (Dosi and Fabiani (1994)).

Selection operates through market mechanisms. This various contibutions represent these mechanisms by a replicator equation. The latter links the market share dynamics to the competitiveness of firms relative to the average competitiveness. The formal definition of competitiveness slightly differs among models. In Chiaromonte and Dosi (1994), competitiveness is measured using prices and unsatisfied demand. In Dosi and Fabiani (1994) and Dosi et al. (1994) economies are open. Authors consider economies as submarkets. Hence when firms act on their domestic markets, competitiveness is the inverse of price. When they operate on a foreign market it also includes the exchange rate. Entry and exit processes resulting from selection are such that every entry corresponds to the exit of a firm. Exit occurs when the market share in a submarket is lower then a given threshold.

Finally mutation operates, as in the Nelson and Winter model, through technological change resulting from the R&D activity. Technical change induce productivity increases. In Dosi and Fabiani (1994) and Dosi et al. (1994), the latter result from innovation or imitation. These processes are stochastic, and quite similar to those used in Nelson and Winter (1982). The success of R&D depends on the employment resources devoted to this activity. The same processes are found in Chiaromonte and Dosi (1993) in the capital good sector. In the consumption good sector, technical progress is deterministic. Firms constantly learn to use the capital goods.

Unlike in Nelson and Winter (1982), where the macro-dynamics are derived from micro-dynamics, these models consider an explicit macro-framework for the micro-dynamics exposed above. All these models adopt a Keynesian vision. Total firms output is derived, and constrained by aggregate demand. Dosi and Fabiani (1994) and Dosi et al. (1994) consider multi-sectorial open economies. Aggregate demand is composed by domestic demand as a constant share of the total wage bill (the other share being devoted to imports), and external demand. Chiaromonte and Dosi (1993) consider a closed economy. Aggregate demand for consumption goods correspond to the total wage bill. The aggregate demand for capital goods is derived from the production (constrained by demand) level of the consumption good. In all these models wages are set at the macro level. Their dynamics is linearly related to labour productivity, employment and consumption price growth rates. Dosi and Fabiani (1994) as well as Dosi et al. (1994) introduce an explicit representation of growth rate dynamics of exchange rates, function of the trade balance and external debt.

More recently Castaldi (2003) has proposed an extension to the Dosi and al. model. The author stresses the importance of geographical distance in the absorption of spillovers directly affecting the growth dynamics.

The open economy models are used to analyse the convergence/divergence patterns of growth rates among countries. The models show a strong tendency towards divergence. According to the authors this in fact reflect the persistence of inter-firms asymmetries in productivity, profits and market shares, and is strongly related to micro-behaviours. Convergence depends on strong conditions on selection (replicator dynamic parameters) and on diffusion and appropriability of technological externalities. Chiaromonte and Dosi (1993) model is used to refine Nelson and Winter (1982) results.

A second group of Evolutionary growth model to be found in the literature develop along the one proposed by Silverberg and Lehnert (1994) and reconsidered in Silverberg and Verspagen (1994, 1995, 1998). These models share a common embodied conception of technical change. Technical progress is assumed to be incorporated in capital vintages.

The Silverberg and Lehnert (1994) model can be described as follows. Production techniques represent the lowest level of aggregation. Heterogeneity occurs at this level with respect to labour productivity embodied in the techniques. New techniques vintages are generated randomly, following a Poisson distribution. By assumption, Silverberg and Lehnert consider that each new technique's labour productivity is a multiple of that of the "best-practice" technique. This multiplicative relation is fixed and constant over time. Thus technological progress would lead to proportional improvements of labour productivity. Adoption of new technologies by producers then depends on the profitability of the techniques. Given wage rates (economy-wide fixed) and output price levels (as each different technique produces one homogeneous good), the diversity of production techniques reflected in the diversity of labour productivity would lead to uneven profit rates.

The selection process follows a replicator mechanism, where the profitability of each production technique is compared to the average profit rate. The techniques for which profitability is above the average are more likely to be adopted and those below would tend to disappear. These selection dynamics would lead to convergence among profitability of techniques towards the 'best practice' techniques. This selection process implies that, at a given moment in time, only a finite number of techniques are still used, representing the most advanced techniques ever discovered within the economy.

These evolutionary micro-mechanisms are then considered within a macro-economic framework directly inspired by Goodwin (1967) model of growth and cycles. Silverberg and Lehnert (1994) consider the co-evolution of employment and wages in explaining short-run cycles along long-run trends.

More precisely, wage dynamics are deterministic, and follow a linear Phillips curve depending on both the wage level and the rate of employment. Employment at the micro level follows the dynamics of capital accumulation, which depend on profits. Capital accumulation influences labour productivity because of the embodied nature of technical progress; the latter will itself influence the dynamics of employment, wages and gross products.

Silverberg and Lehnert use this framework to model both economic growth process and technological long waves. They conclude that innovation clusters do not necessary to lead to the existence of long waves in Schumpeter's analysis. Generating stochastic innovation in this framework might be sufficient to explain the existence of long waves. However, the model concentrates on the diffusion of technical change and its effect on economic growth, overlooking the sources behind the generation of technical change.

In this respect, Silverberg and Verspagen (1994) completes Silverberg Lehnert (1994) model by introducing changes in the strategic mechanisms through 'behavioural learning', and considering micro-founded mechanisms for the generation of technical change. Heterogeneity is considered at the firm level. It concerns the technologies adopted, and firm R&D strategies. Capital vintages are developed within firms. The discovery of new techniques is random. The innovation potential (influencing the probability at which new vintage are discovered) depends on a firm's R&D efforts and on its ability to benefit from spillovers from other firms' R&D efforts. These spillovers might be defined as follows: first firms can catch spillovers from economy-wide R&D spending (weighted by the market share sum of firms' individual R&D levels), and second depending on both economy-wide and firm-specific spillovers. This would also imply that, once an innovation is discovered and introduced into the production process, this would gradually ease other firms' imitation or adoption of this innovation.

Firms are characterised by experiencing learning processes in choosing between innovation and imitation. Firms will choose imitation when their profitability is 'unsatisfactory' with respect to the leading firms (in terms of profits). In this sense, imitation behaviour is endogenously determined and directly depending on its relative technological gap. As a result, the leading firms would less frequently adopt imitative behaviour than laggards ones.

This model provides the following results. First firms' micro-behaviour converge over time to a "stable evolutionary equilibrium" characterised by a positive rate of technical change and R&D investment. Second, within this framework, the initial conditions have a great influence on the steady state, and a low or non-existent rate of R&D would lead to stagnation in a "low growth trap".

Silverberg and Verspagen (1995, 1998) introduce behavioural learning on

R&D investment choices. Firms are still assumed to be bounded rational, following decision rules for their investment choices. The firms are able to learn to invest and renew these decision rules according to their own experience or the others experience. The renewing of decision rules can occur in two ways: Through experimentation, corresponding to a random renewing of the decision rules, or through imitation, corresponding to the adoption of other firms' R&D strategies. The updates in the decision rules are subject to an 'internal selection process'. Hence the firms will stick to their decision rules as long as they remain profitable decisions.

These two last variations of the Silverberg and Lehnert (1994) model then stress the importance of firms behaviour in the dynamics of growth, technical change and market structures.

The last family of models considered here is the so-called 'Technology-Gap' approach. In this framework, economic growth is directly driven by knowledge. A given economy is represented by its knowledge and technological dynamics. This implies that a given economy builds upon its own knowledge stock and/or by exploiting the knowledge spillover from the other economies. The economy dynamics are then directly linked to the interplay of two opposite processes. On the one hand, innovation will increase the innovator knowledge stock, but at the same time increase the technological and then economic gap with its followers. On the other hand, the diffusion of technologies and their adoption through imitation tend to reduce the technological gap.

The Technology-Gap approach considers economic growth as a process that is based on the co-evolution of technological creation and diffusion. Its main aim is to explain inter-country growth rate differentials by this co-evolution.

Fagerberg (1988) models aggregate output, or GDP as an increasing function of knowledge domestically created, knowledge created abroad and the ability of the economy to exploit this knowledge as a base for technological creation. This last component can be seen as the velocity of change in adopting/adapting new technologies or knowledge in production process routines. The existence of this factor can also be seen as representing somehow the macro-competencies of the economy. These competencies allow the economy to combine different knowledge but also to exploit and gain from knowledge creation and diffusion. In this respect this approach can be seen as a macro-view of Nelson and Winter principles founding the evolutionary theory of firms. This macro-competencies cannot be only understood as the aggregation of firm level competencies, but as the whole spectrum of corporate and institutional competencies promoting knowledge diffusion and creation.

In this respect this approach can be seen as a schematic view of what the systems of innovation literature develops there in details.

The diffusion of foreign available knowledge is assumed to follow a logistic functional form. The diffusion of internationally available knowledge depends on the knowledge gap, such as the more the follower knowledge stock reaches the leader one, the longer and more difficult it would be to benefit from the others knowledge. The first technologies to be adopted are the least complex and/or the easiest to reproduce. The remaining ones require more R&D effort or competence increasing has to be done. Note that, as stressed by Fagerberg (1988), imitation might be used by followers to reach the leaders, but this would be insufficient without a gradual transition to innovation-driven technological progress within these countries. This will also mean that competencies to exploit knowledge should gradually be completed by competencies to create knowledge. This quite simple and schematic modelling is rather developed in terms of empirical contribution.

Caniëls and Verspagen (1999) complete the 'traditional' Technology-Gap framework, reconsidering the mechanisms linked to the diffusion of knowledge and technologies among economies (regions). The authors consider a two-dimensional spillover mechanism, including at the same time technological and geographical distance. In this respect the absorption of foreign knowledge is localised and depends simultaneously from the technological gap and geographical neighbourhood. The geographical distance restrains the possibility to reduce the technological gap. The creation of domestic creation of knowledge follows a Kaldor-Verdoorn Law.

Using this model to consider the evolution of patterns of technology gaps among regions, Caniëls and Verspagen (1999) found that with high initial disparities, GDP growth rate differential tends to reduce, rather then increase. Geographical distance as technological distance, however largely influence the catching-up process. The authors revert to the model to reproduce the well-known 'centre-periphery' dynamic of the technology gaps as found in the development literature. The more the periphery region is far from leading centre, the harder the catching-up. This geographical specification aims as well to consider the tacit dimension of knowledge and of understanding, adopting or absorbing technologies.

The principles developed by the 'Technology gap' approach can be found in some recent developments in the cumulative causation approach literature. These are discussed in the following section.

2.3 Towards an Integrated Approach ?

The aim of this chapter is to propose a theoretical base to the formal framework developed in this thesis. This framework builds upon the two approaches exposed in the previous section. These latter, however, only tackles parts of the co-evolving demand dynamics and technical change dynamics explaining growth mechanisms. Our claim is then that it is possible to combine elements of these two approaches and find a unifying formal framework to consider explicitly the interaction channels between macro-evolution and micro-dynamics of technological progress. The last part of this chapter discusses the possibility of merging cumulative causation and evolutionary modelling of the economic growth process, and reviews the rare attempts found in the literature.

2.3.1 Complementarity, Convergences and Divergences

The existence of strong complementarities between the two approaches might allows the integration of these two approaches in a unified framework, modelling the co-evolution of macro-dynamics and technical change. To highlight these complementarities we recall briefly the main features of each of these analytical frames.

On the one hand cumulative causation presents a circular and self-sustained vision of the growth process. The latter is directly linked to the co-evolution of macro-dynamics and technical change. These two processes are interconnected. First macro-dynamics are linked to technical change via the existence of dynamic increasing returns. Second technical change is strongly related to macro-dynamics. Aggregate demand dynamics provides the necessary resources to sustain technical change. However this macroscopic analysis of the growth phenomenon relies on a schematic representation of the mechanisms driving technical change. This representation leads to questionable quasi-automatic and constant improvements in technologies, leaving aside the analysis of the technological processes themselves.

Evolutionary modelling of economic growth, on the other hand, considers technical change as the core process driving macro-dynamics. This stream of literature is devoted to the analysis of the emergence and diffusion of technologies and technical change within the economic systems. In line with the Schumpeterian vision, it considers that the whole economic dynamics are responding to the micro-generated technological dynamics. The emphasis is then put on the analysis of micro determinants and behaviours. The macro-dynamics are the resulting processes of the aggregation of micro-dynamics. The status given to macro-dynamics excludes any explicit consideration about the influence of the latter on the technological dynamics.

Hence where the Kaldorian approach lacks of micro-foundations of the processes driving technological change, evolutionary theories provide an complete set of micro-based dynamics. The emphasis on micro-dynamics however suffers from the lack of macro-foundations. In particular it lacks of a macro-frame allowing feedbacks from the macro-dynamics on the micro-level ones. In other words there is no explicit macro-constraint on the micro-dynamics. This is exactly where the Kaldorian approach completes the evolutionary modelling of the growth process. It emphasises the importance of the macro-structure in absorbing and amplifying the growth impulses emanating from technological dynamics. These growth impulses generate income providing through demand dynamics the resources to sustain technological dynamics.

These two approaches, in addition to their apparent complementarity, also share some common conceptions of the representation of the growth process. This convergence of point of views consolidates the idea to integrate them.

First, these two streams of literature recognise the historical nature of the growth process. This latter is to be found in the common belief that theory is rooted in reality. The modelling of the growth process is in fact based on a set of statistical regularities (i.e. Kaldor's stylised facts among others). Models aim first at reproducing observed growth path rather than generating balanced growth path to empirically tested ex-post as the NGT tends to do. In this respect sticking to facts and history might be seen as an alternative to the NGT quasi-autism towards the empirical reliability of theories.

Second, Kaldorians as well as evolutionary theories on growth recognise the cumulative nature of the growth process. The latter can be linked to the cumulative and irreversible nature of technical change, and/or of knowledge accumulation, as in evolutionary approaches. It can also result from the complex interactions between macro-dynamics and technical change as for the cumulative causation approach. In any case the cumulative nature of the growth process principally relies on the existence of dynamic increasing returns. The presence of the latter generates irreversibility in the technological evolution. This reveals the path dependant nature of the growth path.

These two first points naturally lead the two approaches to converge in the rejection of the equilibrium concept. This leads them to consider 'out-of-equilibrium' approaches to growth rather than the analysis of dynamic equilibria or balanced growth.

When turning to the modelling side of the theories, one can not help to stress some similarities. The way cumulative causation links exports dynamics to competitiveness seems to be an implicit selection process, close to the replicator mechanism to be found in many evolutionary models. Exports grow when competitiveness is higher then the average. This selection process, nevertheless, remains implicit. In this respect cumulative causation already integrates evolutionary principles. This aspect is at the heart of the model developed by Verspagen (1993) as discussed below.

On the evolutionary side, we can build a bridge between Kaldor's 'technical progress function' and the modelling of the R&D process. Hence, starting from Nelson and Winter (1982) up to recent models, technical change as resulting from the R&D process is a function of investments. These latter influence directly the probability of success of the R&D activity. In short, technical change in evolutionary modelling can be considered as stochastic version of the 'technical progress function' developed by Kaldor (1957). Hence, these approaches are not only complementary but also converging in some aspects. In particular this convergence occurs at two levels. First on the formal ground, they share common mechanisms linked to the growth process, such as the existence of dynamic increasing returns, explicit or implicit selection processes and the dependance of technical change to investments. Second, on the methodological ground, they commonly reject the equilibrium vision, considering the growth process as an historical, irreversible and cumulative process.

However, besides this convergence points we have to stress an important point of divergence. This latter concerns the direction of the causal relationships in the models. Kaldorians consider the growth process as resulting from interactions between aggregate demand dynamics and technical change. These interactions occur at the macro-level. This therefore implies that it is the macro-dynamics influence directly the implicit micro-dynamics underlying the Kaldor-Verdoorn Law, displaying in other words a top-down process (from macro-to-micro). Rather, the evolutionary approach clearly considers economic dynamics as a bottom-up process (from micro-to-macro). The dynamics of the economies are the direct consequence of micro-dynamics, and/or micro-behaviours.

Building an integrated approach on these two streams of literature should therefore take into account this divergence of point of view. We believe that it is possible to overcome this divergence. This highlights the necessity, as modeller, to be particularly careful on the functioning of the interaction channels between macro and micro dynamics.

2.3.2 Formal Attempts of Integration:

The frontiers between cumulative causation and evolutionary conceptions of the growth process are not hermetically sealed. These two approaches potentially complete each others and a certain number of authors have already tried to integrate some elements from both streams of literature into the same framework.

The recent developments in the cumulative causation approach largely integrate the principles developed by the 'Technology Gap' literature.[9] These models mainly address the question of the catching-up mechanisms, including the traditional cumulative causation mechanisms to which these models add some mechanisms linked to the diffusion of technologies.

Amable (1993), Leòn Ledesma (2000), Castellacci (2001) or Lorentz (2001), reconsider simply the formal representation of technical change. These models add to the traditional Kaldor-Verdoorn Law some mechanisms favouring the diffusion and adoption of foreign technologies. These modifications aim to include the effect of technological diffusion into the process of catching-up. The latter reduces divergence in growth and productivity, but stresses the importance of adoption/adaptations capacities for the economies to gain from the external flows of technology. It somehow creates an intermediate path to the traditional vicious vs. virtuous circle in explaining growth differentials: the catching-up path, which can be at work either wholly or partially or on the contrary can fail.

Cimoli (1994) and Los and Verspagen (2003) develop multi-sectoral models relying on cumulative causation frameworks, including mechanisms of technological diffusion. These authors link the catching-up in growth and technology to the specialisation patterns. These models add therefore a third dimension in the explaining the growth rates differentials and the catching-up path: the specialisation pattern. The latter plays a crucial role. The structure of the economies condition the effect of the cumulative mechanisms and/or technology diffusion favouring the catching-up process.

These two types of cumulative causation models are however confined to the inclusion of the only technological diffusion mechanisms.

On the evolutionary theory side, only few formal works explicitly introduce cumulative causation modelling in the evolutionary framework. These mainly are the works by Verspagen (1993, 1999, 2002).

Verspagen (1993, chap. 7) proposes an evolutionary re-reading of cumulative causation approach to economic growth modelling. He represents growth

[9] See Castellacci (2001) for a survey.

within a multi-sectoral balance of payment constraint framework. The most disaggregated unit of analysis is the sectoral level. Sectors of a given country differ in terms of goods produced. This would imply that the different sectors might experience different income elasticities inside and among countries.

A selection mechanism is explicitly introduced through a replicator equation, reflecting competition between foreign and domestic producers of a given sector. This reflects the idea that consumers, in the absence of quality differences (reflected in income elasticities), would prefer low-price products. Production costs are endogenously determined as a function of both technological and macro-economic factors, i.e. production costs depend negatively on the technological level of the sector and exchange rates, and positively on wage rates. Wages are determined through productivity growth and the unemployment growth rate, including some persistence, reflecting wage fixation as a path-dependent process. Exchange rates are quite rigid. They adjust slowly to ensure purchasing power parity in the long term. Thus, the selection process is a traditional evolutionary market selection process.

Another selection process applies at a more aggregate level and concerns the sectoral composition of aggregate demand. Hence, following Pasinetti (1981), Verspagen (1993) considers endogenous structural changes in the demand pattern. Income elasticities (for each sector) are a function of the distance between the actual demand level and a predefined satiation level. In this respect the model can generate patterns of sectoral specialisation generating uneven GDP growth rates.[10]

Verspagen' s specification of technological progress is directly rooted in the Kaldorian tradition as it is modelled using the Kaldor-Verdoorn Law. This approach of technical progress is, in his own words, 'stylised' and "does not involve endogenous investment in R&D[...]". Technological change is however endogenously determined through dynamic increasing returns represented by the Kaldor-Verdoorn Law. Concerning his approach to technical change, Verspagen (1993) is then rather closer to the Kaldorian tradition than to the Nelson and Winter search process approach.

His framework is developed to analyse the influences of a country's integration into worldwide trade and of its technological level on the growth rates constrained by trade balances, and more precisely, to analyse effects of differences in technological competence between countries, on the growth rate differential among nations. The multi-sectoral aspect of his analysis allows him to consider endogenous specialisation patterns. Cumulative characteristics of growth, technical change and wages tend then to bring about an

[10] A country leading in a given sector could grow slower then others if it is specialised in low growing sectors.

explicit tendency towards industrial specialisation. This aspect was assumed in the Kaldorian growth analysis, but is justified in this framework by the evolutionary selection mechanisms. This model tends to highlight clear relations between sectorial specialisation, technological change, and the growth process. These processes are both interdependent and self-reinforcing.

Verspagen (1999, 2002) proposes a slightly different approach. The model uses a schematic multi-sectorial representation of the Dutch economy directly inspired by Keynesian macro-economics. The structure of the economy explicitly considers the interaction structure among sectors, with the use of an input/output matrix as an aggregate representation of the production capacities. Following the Kaldorian tradition, Verspagen considers that long run growth is linked to external demand. The computation of the aggregate demand dynamics is deduced from the balance of payment constraint. He obtains a reduced form for GDP growth rates including the sectorial interactions within what can be considered as a trade multiplier. The dynamics of external demand are modelled using a replicator equation. External demand is function of the competitiveness of the economy.

The framework presented aims to analyse the effect of different scenarios on the macro-dynamics, through their diffusion along the economy. The author concentrates on two types of scenarios: competitiveness shocks and technological shocks. The first scenario induces some modifications in the growth impulse generated by external demand dynamics. The second affects the factors coefficient of the input/output matrix. These shocks will affect the structure of the economy. For a given growth impulse generated by external demand, it is then the propagation of these growth impulse that will be modified. Technical change is not endogenously considered in this model. Its interest for us is exactly that it demonstrate that the macro-economic framework itself strongly influences the macro-dynamics, by defining and constraining the diffusion channels of growth impulses.

These two formal integration of cumulative causation and evolutionary elements into the same frameworks are nevertheless limited and remain macro-centred. First, Verspagen (1993) proposes an evolutionary re-interpretation of the international competitions components of the cumulative causation approach introducing explicit selection mechanisms. Second, Verspagen (1999, 2002) injects in a Post-Keynesien framework random shocks in the structure and the competitiveness. These latter induce some of the uncertain nature of technical change found in the evolutionary literature. These two approaches, however, do not develop any micro-foundations. This leaves room for a cumulative causation framework that includes evolutionary micro-founded technological change.

2.4 Concluding remarks

We have aimed along this chapter to build the theoretical base for the approach to endogenous growth processes. This theoretical base relies on two heterodox approaches to the analysis of economic growth: the cumulative causation framework and the formalised branch of the evolutionary analysis of economic growth.

Our aim is to tackle the possible interactions between macro and technological dynamics. This implies that we consider not only the way technical change generates productivity increases and then GDP growth, as it is usually considered in the mainstream growth theory. We also include the analysis of the possible influence of macro-dynamics on technological change itself. Such an analysis then requires a framework that considers at the same time a clear understanding of the emergence and diffusion of technologies and of the macro-economic framework and mechanisms underlying the growth process.

The two considered approaches seem, as we argued in this chapter, to complete each other in describing these mechanisms. Hence when cumulative causation approach provides a complete description of the macro-mechanisms underlying the growth process, its description of technological dynamics remains schematic. It however helps considering the channel through which technical change contributes to economic growth, generating income and then demand allowing GDP growth. But it also underlines the importance of macro-dynamics in generating the resources necessary for technical change to occur. This last point might be one of the weaknesses of evolutionary models. These latter, on the other side, provide a more complete analysis of the emergence and diffusion of technologies at a micro-level, stressing the importance of firms behaviours in terms of R&D activity and investment behaviours, and the role of competition through the selection mechanisms.

This disclosed complementarity leads us to integrate the two approaches within the same framework. This would provide us with a modelling of the growth process allowing for a more complete analysis of the interactions between macro-dynamics and technical change. Few formal attempts can be found in the literature trying to achieve this merging.

We cconsidered two examples, Verspagen (1993), Verspagen (1999, 2002). Both show an analysis of growth mechanisms which bridges together Post-Keynesien and Evolutionary frameworks.

Verspagen (1993) reconsiders the cumulative causation framework introducing explicit selection mechanisms, while in his later contributions, he considers the diffusion of stochastic technological shocks within an economy through the sectoral interaction and its effect on growth.

All these models nevertheless share a common limitation: none of them really micro-found the technological change mechanisms, which remain macro-focused. This leaves room for the formal developments proposed in this thesis.

Outline of the Thesis

The aim of this thesis is to provide an alternative analysis of growth rates differences across economies, which merges both Post-Keynesian and Schumpeterian approaches. We rely on the strong complementarity of these two approaches, as stressed in the previous chapter. On the one hand, the Kaldorian cumulative causation theory provides Schumpeterian's stream of contributions with a more embracing macro-economic framework, able to capture the macro-constraints affecting the micro-dynamics of firms' behaviour. On the other hand, the Evolutionary/Schumpeterian approach provides Kaldorians with a micro-founded the dynamics of technological change.

In line with both the post-Keynesian and the Schumpeterian streams of literature, this work draws upon the rejection of mainstream equilibrium-centred analysis and aims to provide an out-of-equilibrium analysis of the growth process.

Unlike the (few) existing attempts to merge these two views on the growth mechanisms, our approach introduces an explicit micro-dimension. In line with the Schumpeterians, we root the existence of increasing returns in the micro-dynamics leading to the emergence and diffusion of technologies. The macro-economic framework, inspired by the Post-Keynesian literature takes into account these micro-dynamics. The thesis is organised as follows.

Following the introductive part (Chapters 1, 2), the second part of this work focuses on the analysis of increasing returns and productivity dynamics by relying on the use of the Kaldor-Verdoorn Law. The simplicity of the functional form allows for a simple methodological alternative for the empirical identification of the existence of increasing returns at the aggregated level. However, the relevance of the law has been questioned by the literature; first due to the arising of new production tools and the emergence of new sectors of activity after the 70's crisis; second due to the sensitiveness of the sample of country used for the empirical estimation.

In Chapter 3 we first estimate the law at the macro level across-countries for the last 50 years, and on various samples of countries. The empirical investigations aim to test whether the law still holds today. Second, we estimate the law at the sectoral level, across-countries, for the last 20 years. In this second case, we aim to test whether the law holds for most of the industrial sectors or if the increasing returns remains limited to the manufacturing activities as it was claimed by Kaldor.

Overall, we check whether evidence of the existence of increasing returns, at the macro as well as the sectoral level, exists. Nevertheless, the empirical estimation of the Kaldor-Verdoorn Law as such does not offer any indications on the sources of these increasing returns. In order to explore these sources, in Chapter 4 we draw upon an evolutionary micro-founded model of technical change. The latter represents a population of heterogeneous and bounded rational firms. These firms are subject to endogenous mutations in their technological characteristics and try to survive the market selection mechanisms. The simulations first aim to test whether the Kaldor-Verdoorn Law emerges as an aggregated property of these micro dynamics. Second simulations carried out in Chapter 4 aim to show that the various micro-characteristics might have a direct effect on the value, significance and explanatory power of the law.

In the third part of the work (Chapters 5, 6, 7), we synthesise the Kaldorian and neo-Schumpeterian streams of literature into macro simulation models. The models provide evolutionary micro-foundations for technical change. The latter are similar to the model described above. These micro-dynamics are then integrated within macro-frames inspired by the cumulative causation models. In particular, macro-dynamics rely on demand dynamics, which affect firms' ability to invest and therefore to mutate. These macro-dynamics are themselves subject to the micro-level productivity dynamics. The macro-components act on the micro-dynamics as macro-constraints. These latter are themselves directly affected by micro-dynamics. Our models therefore integrate to the evolutionary frame a set of feedback mechanisms from macro-to-micro but also from micro-to-macro. This part of our thesis proposes three distinct models.

In Chapter 5, we develop a one-sector growth model where the macro-frame is directly inspired by the one proposed in Dixon and Thirlwall (1975) and Thirlwall (1979) modelling of Kaldor's cumulative causation. Aggregate demand dynamics is there function of its external component through a multiplier deduced from the balance of payment constraint. Simulations test the conditions leading to the emergence of divergence regimes. We focus on the effects of demand and technology characteristics and on the micro-to-macro mechanisms as affecting the growth differentials.

A second model (Chapter 6) extends this analysis by introducing a multi-sectoral dimension to the balance of payment constraint based model of aggregate demand dynamics. This model allows us to stress the role of sectoral specialisation in generating growth rate differences. Also in this case, we make use of the simulations tool to identify the sources of sectoral specialisation patterns and test the influence of these patterns on growth differential.

Finally, a third model (Chapter 7) proposes to release the balance of payment constraint and introduces sectoral interdependencies in demand dynamics as well as in satiation levels. With this model we aim to highlight the importance of the sectoral structure of economies as well as structural changes in explaining growth rates differences. The simulations carried out in this chapter test whether the introduction of satiation levels and the changes operated in the demand structure affect the patterns of growth differences.

The main goal of these three models is to show that the macro-constraints are crucial in generating growth rates differences. First, the micro-dynamics of technical change might only affect macro-dynamics *via* macro-mechanisms. Second, the nature and structure of aggregate demand should shape macro-dynamics, which in turn directly affect micro-dynamics.

Finally, in Chapter 8 we provide a summary of the findings. We then discuss these results and the potential developments of the approach proposed in this thesis.

Part II

Productivity Dynamics And Technical Change: Towards Evolutionary Micro-Foundations Of The Kaldor-Verdoorn Law

Introduction

The second part of our thesis focuses of the technological component of the growth process. More precisely we choose to analyse productivity dynamics as a process driven by the existence of increasing returns.

Most of the theoretical approaches to economic growth consider technical change as a key factor for growth. In this respect, technical change is usually related to the existence of increasing returns. From A. Smith to the latest New Growth Theory (NGT), increasing returns are presented as the major engine for long-run growth. Among all these theoretical approaches, Kaldor's cumulative causation as well as the Evolutionary/Schumpeterian approaches shares this view. These two streams of literature, however, diverge in the way they formalise increasing returns, as stressed in Chapter 2.

Within the Evolutionary framework, and following Schumpeter's precepts, technical change emerges at the micro-level and diffuses into the economy, triggering the macro-dynamics. The existence of increasing returns is rooted in these micro-dynamics leading to the emergence and diffusion of technology. The increasing returns are therefore intrinsically dynamic. However, increasing returns do not represent a prerequisite for technical change to occur, as in the NGT, but rather they can be considered an emergent property of the micro-dynamics of technical change.

For the Kaldorians, technical change is only one of the components responsible for the cumulative causations underlying the growth process. Technical change within this framework relies on the existence of static and dynamic increasing returns. These latter are therefore a prerequisite for technical change to occur. For Kaldor, increasing returns are rooted in large-scale manufacturing activities, in line with the Smithian concept of static increasing returns, and in the renewal of production capacities through investments. Finally, increasing returns are also due to the macro-level division of labour as described by Young (1928). Kaldor (1966) supports this analysis by re-interpreting the empirical evidences provided by Verdoorn (1949), which shows a positive, robust and significant relationship between labour productivity on the one hand, and employment growth rates on the other one, and gross product's growth rate. This relationship is known as the Kaldor-Verdoorn Law.

We aim along this part of our thesis to build a bridge between these two, seemingly divergent views on increasing returns. We try to show that a Kaldor-Verdoorn Law emerges as a property of the micro-dynamics generated by an evolutionary micro-model. This second part of our thesis is organised as follows.

Chapter 3 proposes to estimate the law at the macro level across-countries for the last 50 years, and on various samples of countries. The empirical analysis tests whether the law still holds today. In the chapter we also estimate the law for 56 industrial activities, for the last 20 years. In this second case, we test whether the law holds for most of the sectors or if the increasing returns remain confined to the manufacturing activities as Kaldor claimed[11].

Chapter 4 draws upon an evolutionary micro-founded model of technical change to explore the sources of increasing returns highlighted by the Kaldor-Verdoorn Law. The model relies on a population of heterogeneous and bounded rational firms that are subject to endogenous mutations in their production technologies and that try to survive the market selection mechanisms. We first test whether the Kaldor-Verdoorn Law emerges as an emergent property of the micro-dynamics generated by the model. Second the simulations aim to test the effect of various micro-characteristics on the value, significance and robustness of the law.

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> "I am not suggesting that the Verdoorn relationship applies *only* to manufacturing activities or that it applies to every manufacturing industry considered separately. But its application outside the industrial field is clearly far more limited." (Kaldor (1966) p. 16)

Chapter 3

Does The Kaldor-Verdoorn Law Still Mean Something?

As pointed in Chapter 2, Kaldor's cumulative causation mechanisms underlying the growth process relies on two main components. The first one is the demand dynamics, the second one technical change (Kaldor (1966, 1972, 1981)). This latter relies on the existence of increasing returns, which can be either static or dynamic. Kaldor's analysis of the increasing returns reverts to the one proposed by Young (1928), who attributes them to a large scale division of labour, the enlarging of the existing markets and the creation of new activities.[1]

For Kaldor (1966), Verdoorn's (1949) empirical analysis clearly supports the hypothesis of the existence of these dynamic increasing returns:

> "This [i.e. dynamic increasing returns], in my view, is the basic reason for the empirical relationship between the growth of productivity and the growth of production which has recently come to be known as the 'Verdoorn Law' [...]. It is dynamic rather than a static relationship... primarily because technical progress enters into it, and not just a reflection of the economies of large-scale production." (Kaldor (1966) p. 10)

Verdoorn's (1949) article aimed to find a method to forecast changes in labour

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[1]

> "In addition, as Allyn Young emphasised, increasing returns is a 'macro-phenomenon' -just because so much of the economies of scale emerge as a result of increased differentiation, the emergence of new processes and new subsidiary industries, they cannot be 'disconnected adequately by observing the effect of variations in the size of an individual firm or of a particular industry'. (Kaldor (1966) p.9-10)"

productivity. As a matter of fact, his empirical investigations stressed the existence of a constant relationship between growth rates of labour productivity and of production for the pre- and the post-World War I periods for a selected number of countries.[2]

These results have been interpreted by Kaldor (1966) as supporting the existence of dynamic increasing returns. He himself estimated the same relationship for the period 1953-1963 using a sample of 12 countries[3]. Further, he estimated a relation between employment and production growth rates. Both the empirical relationships appeared to be significant and robust, and became known as the Kaldor Verdoorn Law.

The simplicity of the functional form at the basis of the Kaldor Verdoorn law represented a simple alternative to forecast productivity changes or to quantify the magnitude of the increasing returns. This might explain the wide popularity of the law. McCombie, Pugno and Soro (2002) counted more than 80 papers making use of the Kaldor-Verdoorn Law since Verdoorn (1949) article. Most of these contributions make use of the law to measure increasing returns for specific countries, regions or sectors and/or account for differences among these latter.

Unlike the above-mentioned contributions, in this chapter we aim to test whether the Law, as originally estimated by Kaldor (1966) still holds rather use the law for country or sector comparisons. This is motivated by the arising of some critics on the reliability of the Law since the late 1970.

For instance, Rowthorn (1975) strongly questioned Kaldor's estimates. He showed that the results of the estimations dramatically change depending on whether Japan was included or not in the sample. Once Japan was excluded, the empirical analysis showed constant or even decreasing returns, depending on the time period. Even so, Kaldor (1975), in replying to Rowthorn, stressed the difference in the specification estimated, claiming that the one used by Rowthorn was more sensitive to short run effects. In other terms, he pointed out the possible sensitiveness of the estimation results to the inclusion of outlier such as fast growing countries. This debate remains still open in the Kaldor-Verdoorn Law literature.

Boyer and Petit (1981, 1991), brought evidences that from 1970 onwards, and for a selected number of advanced economies, the Law seems not to hold anymore. For Boyer and Petit, this evidence can be attributed to the dra-

[2] The countries included in the analysis were, depending on the period, Switzerland, UK, USA, Germany, Japan, Finland, Hungary, Holland, Norway, Poland, Canada, Czechoslovakia, Estonia and Italy.

[3] Austria, Belgium, Canada, Denmark, France, West Germany, Italy, Japan, Netherlands, Norway, UK and USA.

matic changes in the sectoral structure of these economies that occurred over the same period. Among these, they claim that the growth of tertiary sectors and/or the shift from embodied to R&D based technical change are responsible for the evidences found by Boyer and Petit (1981). The traditional sources of increasing returns, such as manufacturing activities are gradually left aside. More recent empirical investigations, as Knell (2004), however, seem to show that the law tends to become significant again, from the 1990s onwards. of significance of the law from 1990 onwards.

In Section 3.1 we test whether the Kaldor-Verdoorn holds at the aggregate level, using a cross-country estimation of the Law for the last five decades using various samples of countries.

Section 3.2 presents an empirical estimation of the Law for 56 industrial sectors for the last 20 decades. The aim of this second section is to test whether the Kaldor-Verdoorn Law is verified at the sectoral level.

The last section summarises and discusses some ambiguous results of the empirical analyses.

3.1 A Macroscopic approach of the Kaldor-Verdoorn Law

The first section of this chapter proposes to estimate the Kaldor-Verdoorn Law at the macro-level using a cross-country estimation for various time periods. We reproduce a similar procedure to the one used by Kaldor (1966). This first set of estimates aims to test whether the law holds over the various time periods.

We choose to estimate the two forms of the law:

- The *'Verdoorn specification'* links the growth rate of productivity (p) to the growth rate of gross product (y). Formally this specification takes the following form:

$$p = a_1 + a_2 y \tag{3.1}$$

  We consider that the Kaldor-Verdoorn Law holds if the estimated values of the Verdoorn coefficient (a_2) is significantly positive and different from zero. In this case, the higher the value of the Verdoorn coefficient, the higher the increasing returns are.

- The *'Kaldor specification'* links the growth rate of employment (e) to the growth rate of GDP (y). This specification is represented by the equation that follows:

$$e = b_1 + b_2 y \tag{3.2}$$

The Kaldor-Verdoorn Law holds if the estimated value of b_2 is significantly lower than one. When b_2 equals one, this corresponds to the case of constant returns to scale.

The two specifications are equivalent. We can easily show this starting from the Verdoorn specification. Labour productivity is defined as the ratio of gross product over total employment. Its growth rate can be expressed as the differences between gross product and employment growth rates:

$$p = y - e$$

The Verdoorn specification can the be rewritten as:

$$y - e = a_1 + a_2 y$$

$$e = -a_1 + (1 - a_2)y$$

If the Kaldor-Verdoorn Law holds, then a_2 is significantly different from zero and simultaneously b_2 is significantly different from one. Hence when b_2 is not significantly different from zero:

- if a_2 is significantly different from zero, the law holds with high increasing returns.

- if a_2 is not significantly different from zero, then not only the law does not hold but there is no significant relationship between employment, labour productivity and GDP growth rates.

The data-set used for this section is derived from the 2004 "Groningen Growth & Development Center & The Conference Board, Total Economy Database"[4]. More specifically, our data-set relies on the Real GDP and Real GDP per hours in constant 1990 US dollars time series for the period 1949 to 2000, for a selected number of countries. We build a cross-country sample for GDP, employment and labour productivity growth rates for these five time decades.

Following Kaldor (1966), we choose to estimate the Kaldor-Verdoorn Law using the decades' growth rates. These latter are computed as the growth rates between the average values over the two initial and the average over the two last years of a given decade. We used an average over two periods

[4]available at http://www.ggdc.net

to limit the effect of short run picks. Hence for the periode 1950-1960, the growth rates of a variable X is computed as follows:

$$\frac{\left(\frac{X_{1959}+X_{1960}}{2}\right) - \left(\frac{X_{1949}+X_{1950}}{2}\right)}{\left(\frac{X_{1959}+X_{1960}}{2}\right)}$$

Note that estimations realised using the average annual growth rates exhibits similar results. We then revert to the decades growth rates as a reference point with Kaldor (1966).

The data-set is divided in three different samples of countries. These are presented in Tables 3.5 and 3.10. This sub-division corresponds to the three set of estimations presented in this section:

- The first sample corresponds to the sample of 12 countries originally used by Kaldor (1966).
- The second sample adds to the first all the pre-1974 OECD members.
- The third sample adds to the second one a selected number of Eastern European, Latin American and Asian countries.

The detailed data-set used in this section can be found in appendix.

3.1.1 Estimating the Kaldor-Verdoorn Law using Kaldor's sample

We first propose to estimate the Kaldor-Verdoorn Law for the sample of country originally used by Kaldor (1966) : Austria, Belgium, Canada, Denmark, France, West Germany, Italy, Japan, Netherlands, Norway, UK and USA. We refer to this sample as the *'Kaldor's sample'*. We test the law using a cross-country estimation for the five decades: 1950-1960, 1960-1970, 1970-1980, 1980-1990 and 1990-2000. The first decade corresponds to the period used by Kaldor (1966). We then revert to this specific period as a point of comparison with Kaldor's results.

We first estimate the Verdoorn specification (Equation 3.1) that links labour productivity growth rates (p) to GDP growth rate. Figure 3.1 shows for every time periods, the labour productivity growth rate versus GDP growth rate scatter plots.

We use the ordinary least square method to estimate the Verdoorn specification of the Law. Table 3.1 presents the results of the estimation for the different time periods. These estimations of the Verdoorn specification using *Kaldor's sample* shows the following results:

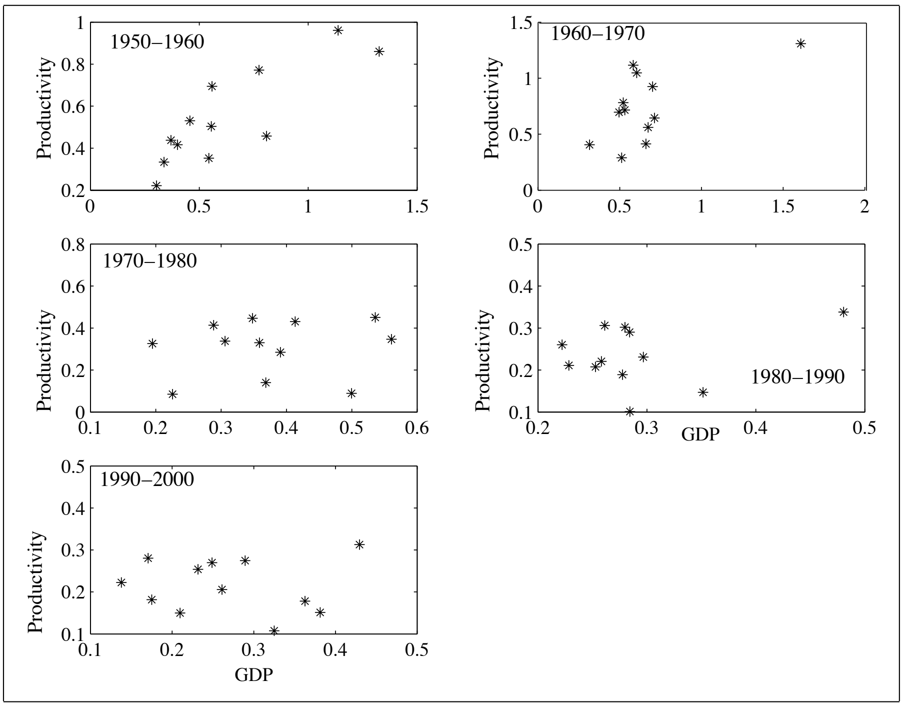

Figure 3.1: Labour Productivity vs. GDP decades growth rates (*Kaldor's sample*)

Table 3.1: Estimates for the Verdoorn specification with *Kaldor's sample*

	a_1	a_2	R^2	R_c^2	F
1950-1960	0.1714 (2.0373)	0.5925 (4.9509)	0.7102	0.6813	24.5115
1960-1970	0.3411 (1.9512)	0.6077 (2.5274)	0.3898	0.3288	6.3880
1970-1980	0.2476 (1.7497)	0.1579 (0.4354)	0.0186	-0.0795	0.1896
1980-1990	0.1577 (1.7213)	0.2620 (0.8497)	0.0673	-0.0259	0.7220
1990-2000	0.2232 (3.5930)	-0.0282 (-0.1284)	0.0016	-0.0982	0.0165
Sample size	12				

The main result coming out from the estimations is that the Kaldor-Verdoorn Law is verified until the 1970's. The Verdoorn coefficient is significantly different from zero only for the two first periods. For the first period (1950-1960), the results are similar to Kaldor (1966). For the same period, the robustness of the relationship is quite high ($R^2 = 0.7102$). The latter drops over time. From the 70s on, the Verdoorn coefficient estimates are no more significant. These seems to decrease over time.

We then test the differences in the estimates of the Verdoorn coefficient (a_2) among time period. Table 3.2 presents the t-values for a_2 (line) being equal to a_2 (column) time periodes.

Table 3.2: Differences in a_2 across 5 decades (T-test)

	1950-1960	1960-1970	1970-1980	1980-1990	1990-2000
1950-1960	0	-0.1271	3.6314	2.7612	5.1870
1960-1970	0.0633	0	1.8707	1.4376	2.6449
1970-1980	-1.4533	-1.2402	0	-0.2871	0.5133
1980-1990	-1.0715	-1.1208	0.3377	0	0.9413
1990-2000	-2.8225	-2.8916	-0.8465	-1.3200	0

The results presented in this table shows us first that the estimates for the Verdoorn coefficient only gradually differ. The clear-cut difference found in the estimates, before and after 1970 is not as clear when the estimates are compared pair-wise. The value of the coefficient for the 50s is significantly higher than the estimates after 1970. The Verdoorn coefficient for the 90s is significantly lower than the estimates before 1970. The results from the test are more ambiguous for the intermediate periods, namely the 60s, 70s and 80s. Hence the differences in the elasticity of productivity growth to GDP growth rates are no more significant for these three decades. This quite puzzling result can be interpreted as a gradual decrease in the value and significance of the estimated Verdoorn coefficient rather than a clear cut change after 1970.

We then estimate the Kaldor specification of the law that links the growth rate of employment to the growth rate of GDP (Equation 3.2). Figure 3.2 presents employment growth rates versus GDP growth rates for the five decades considered.

We used the ordinary least square method to estimate this relationship. The results are presented in Tables 3.3 and 3.4.

The empirical analysis confirms those previously found with the Verdoorn specification. The estimated b_2 are significantly different from zero for every time period (except the 60s). There exist a relationship between employment and GDP growth rates. However, the law holds only for the two first periodes. b_2 is only significantly lower than one for the 50s and the 60s. From 1970, the estimated value for b_2 is no more significantly different from one.

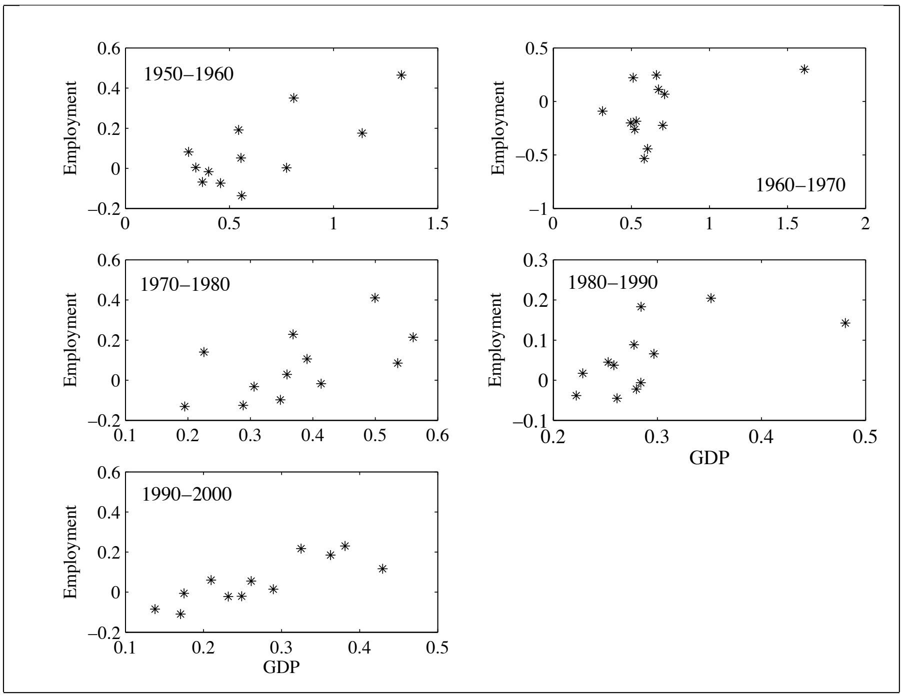

Figure 3.2: Employment vs. GDP decades growth rates (*Kaldor's sample*)

The results found therefore confirm that from 1970 the law does not hold anymore. This might lead us to infer that from 1970 onwards these economies are characterised by constant returns to scale.

The results found in this first set of estimates can be summarised as follows:

Result 1 *The estimates carried out on the sample of countries used by Kaldor (1966) show that the Kaldor-Verdoorn Law only hold during the 50s and 60s. From 1970 onwards, constant returns to scale replaced the increasing returns found for the 50s and the 60s. This shift has occurred gradually as shown by one of T-tests.*

As stressed by Boyer and Petit (1981), these results can be explained by the fact that the Kaldor-Verdoorn Law corresponds to a specific structure of the economy, driven by industrial and manufacturing activities. From the 70's on the most advanced countries experienced first an important crisis in the industrial activities. The economies completing the switch from manufacturing-driven growth to a service-driven growth. Second, within industrial and manufacturing sectors, these economies experienced important mutations in both their production structures, and demand regimes (Boyer

Table 3.3: Estimates for the Kaldor specification using *Kaldor's sample*

	b_1	b_2	R^2	R_c^2	F
1950-1960	-0.1714 (-2.0373)	0.4075 (3.4054)	0.5370	0.4907	11.5965
1960-1970	-0.3411 (-1.9512)	0.3923 (1.6317)	0.2103	0.1313	2.6623
1970-1980	-0.2476 (-1.7497)	0.8421 (2.3220)	0.3503	0.2853	5.3918
1980-1990	-0.1577 (-1.7213)	0.7380 (2.3930)	0.3641	0.3005	5.7263
1990-2000	-0.2232 (-3.5930)	1.0282 (4.6755)	0.6861	0.6547	21.8601
Sample size	12				

Table 3.4: T-test b_1, b_2 equal to 1

	t (b_1=1)	t (b_2=1)
1950 - 1960	-13.9226	-4.9509
1960 - 1970	-7.6713	-2.5274
1970 - 1980	-8.8172	-0.4354
1980 - 1990	-12.6336	-0.8497
1990 - 2000	-19.6906	0.1284

and Petit (1989)). All these factors might explain why the law does not hold anymore. This shows the gradual shift from increasing to non-increasing returns.

3.1.2 Extending the estimation to the Pre-1974 OECD members

The second set of estimations proposes to estimate the Kaldor-Verdoorn Law enlarging the sample of countries. We use a sample of 22 Pre-1974 OECD members (*OECD sample*), for the five time periods considered.

This sample of countries includes the following countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, West Germany, Greece, Ireland, Italy, Japan, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and the United States.We refer to this sample as the *'OECD sample'*. Among these twelve were already included in the previous sample. The list of countries included respectively

Table 3.5: Kaldor (1966) and Pre-1974 OECD members samples of countries

Kaldor's sample	OECD sample
	Australia
Austria	Austria
Belgium	Belgium
Canada	Canada
Denmark	Denmark
	Finland
France	France
W. Germany	W. Germany
	Greece
	Ireland
Italy	Italy
Japan	Japan
	Luxembourg
Netherlands	Netherlands
Norway	Norway
	Portugal
	Spain
	Sweden
	Switzerland
	Turkey
U.K.	U.K.
U.S.A	U.S.A

in the *Kaldor* and the *OECD* samples are provided in Table 3.5. Figure 3.3 presents for every considered decades labour productivity growth rates vs. GDP growth rates.

We use the ordinary least square method to estimate the law on the *OECD sample*, for every time periods. The estimation results for the Verdoorn specification are presented in Table 3.6. The enlargement of the sample drastically changed the results obtained in the previous section. The main result coming out from these estimations is that, except for the period 1970-1980, the Kaldor-Verdoorn Law holds.

For the 50s, 60s, 80s and 90s the estimated value of the Verdoorn coefficient (a_2) is significantly different fro zero. Contrary to the results found with the *Kaldor sample*, from 1980 on, the Kaldor-Verdoorn Law holds again. The estimates for the 50s are closed to the one found with the *Kaldor sample*, themselves similar to Kaldor (1966). From 1960-1970 onwards, the inclusion of new countries has brought about the evidence that the values of the Verdoorn coefficient are higher than with the *Kaldor sample*.

We then revert to a T-test to test the significance of the differences in the estimates of the Verdoorn coefficient (a_2) across the 5 decades. For each

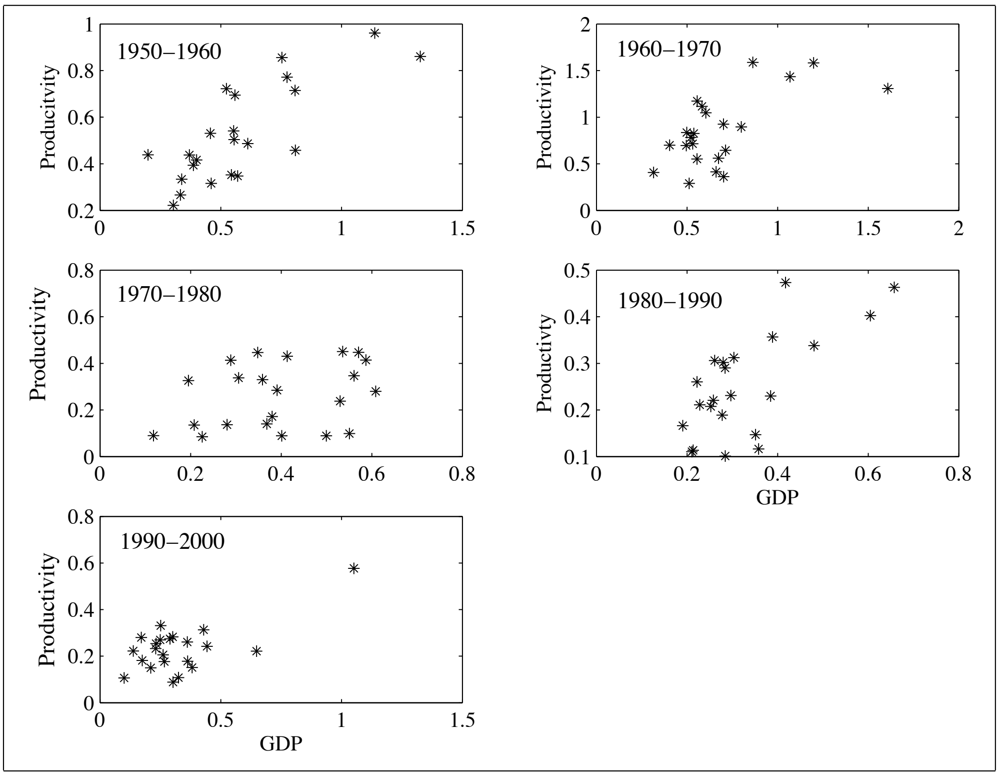

Figure 3.3: Labour productivity vs. GDP decades growth rates (*OECD sample*)

Table 3.6: Estimates for the Verdoorn specification using the *OECD sample*

	a_1	a_2	R^2	R_c^2	F
1950-1960	0.1746 (2.5273)	0.6096 (5.6268)	0.6129	0.5935	31.6605
1960-1970	0.2739 (1.6202)	0.8493 (3.7287)	0.4101	0.3806	13.9033
1970-1980	0.1389 (1.6140)	0.3122 (1.5259)	0.1043	0.0595	2.3284
1980-1990	0.0488 (0.9717)	0.6211 (4.3188)	0.4826	0.4567	18.6524
1990-2000	0.1227 (3.7624)	0.3354 (3.9144)	0.4338	0.4055	15.3222
Sample size	22				

time period the estimated coefficient is compared to all the other time periodes. The Table 3.7 reports the results of this test. These latter show the significance of the differences in the estimated values among time peri-

Table 3.7: Differences in a_2 across time (T-test)

	1950-1960	1960-1970	1970-1980	1980-1990	1990-2000
1950-1960	0	-2.2126	2.7448	-0.1059	2.5309
1960-1970	1.0524	0	2.3580	1.0021	2.2562
1970-1980	-1.4533	-2.6248	0	-1.5094	-0.1132
1980-1990	0.0798	-1.5872	2.1477	0	1.9865
1990-2000	-3.2001	-5.9978	0.2704	-3.3340	0

ods. We can distinguish two groups : First, the Verdoorn coefficients for the periods 1950-1960, 1960-1970 and 1980-1990 are not significantly different to each other, but significantly higher than the estimates for 1970-1980 and 1990-2000. Second, the Verdoorn coefficient for the periods 1970-1980 and 1990-2000, are not significantly different from each other, but significantly lower then the other estimates. This last result might be puzzling, given that the estimates appeared to be significantly different from zero for 1990-2000 and not significantly different from zero for the 1970-1980. Figure 3.3 show us that for the 90s, the outcome of the estimation might have been influenced by the presence of an outlier point (Ireland). As a matter of fact this explanation is in line with Rowthorn (1975) that stressed the sensitiveness of the estimation results of the Kaldor-Verdoorn Law to the presence in the sample of fast-growing economies, as Japan in the 1950s.

In a second phase, we estimate the Kaldor-Verdoorn Law using Kaldor's specification with the *OECD sample*. Figure 3.4 presents employment growth rates versus the GDP growth rates for the five time periods.

We used the ordinary least square method to estimate this relationship. The results are presented in Tables 3.8 and 3.9. These latter confirm the findings of the estimations for the Verdoorn specification. The law holds for every time period. For almost all periods, the estimated value for b_2 is significantly different from zero (Table 3.8). These estimates appear significantly lower than one for every time periods (Table 3.9).

We highlight, however, that contrary to the Verdoorn specification that showed a non-significant value for a_2 for 1970-1980, the estimates of the Kaldor specification are significantly different from zero and lower than one fro the same period. This shows the existence of increasing returns for this period. Moreover, the estimates for the period 1960-1970, appeared not to be be significantly different from zero. This results does not imply that the law does not hold. Given the high value of the estimated Verdoorn coefficient (b_2), the estimate for the Kaldor specification should mechanically tend to

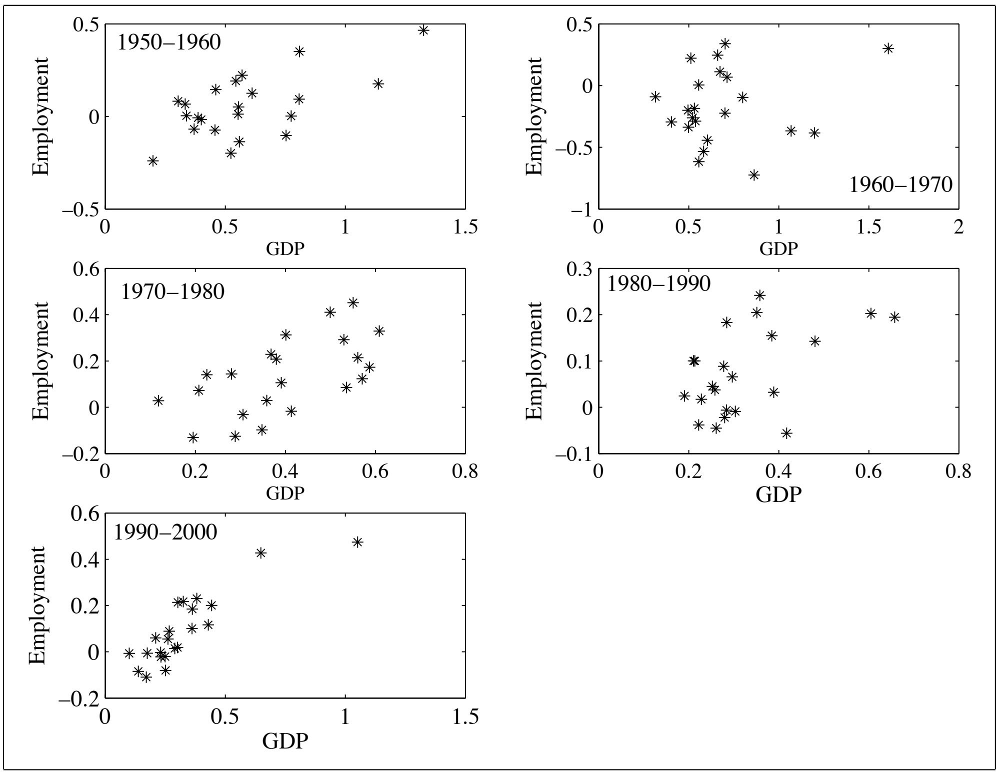

Figure 3.4: Employment vs. GDP decades growth rates (*OECD sample*)

Table 3.8: Estimates for the Kaldor specification using the *OECD sample*

	b_1	b_2	R^2	R_c^2	F
1950-1960	-0.0147 (-2.7309)	0.4072 (3.6341)	0.3977	0.3676	13.2066
1960-1970	-0.0096 (-1.1451)	0.2551 (1.6006)	0.1136	0.0692	2.5621
1970-1980	-0.0144 (-2.1989)	0.4995 (2.5839)	0.2503	0.2128	6.6763
1980-1990	-0.0038 (-0.8533)	0.3178 (1.9990)	0.1665	0.1249	3.9961
1990-2000	-0.0102 (-3.0287)	0.6486 (5.2787)	0.5822	0.5613	27.8645
Sample size	22				

zero.

The results found estimating the law using the *OECD sample* can be summarised as follows:

Table 3.9: T-test for b_1, b_2 equal to 1

	t (b_1=1)	t (b_2=1)
1950 - 1960	-187.9058	-5.2910
1960 - 1970	-119.8300	-4.6746
1970 - 1980	-154.9251	-2.5888
1980 - 1990	-225.7826	-4.2919
1990 - 2000	-301.0036	-2.8596

Result 2 *Enlarging the sample used to estimate the Kaldor-Verdoorn Law to the entire pre-1974 OECD member countries led to different results then those found previously. If the initial periods exhibits comparable results, the Kaldor-Verdoorn Law appeared to hold also after 1980. An ambiguity however persists concerning the 1970s.*

To explain these results we can refer to two possible point of views :

First, the explanation of the drastic changes in the estimates can then be due to technical reasons, in line with Rowthorn (1975). He pointed out the high sensitiveness of the estimates of the law to outlier economies such as fast growing economies or declining economies. He highlighted the case of UK or Japan as playing these roles in Kaldor's (1966) estimates. Figures 3.3 and 3.3, shows this type of outlier point for the 1990s, which corresponds to Ireland. The latter experienced fast growth rates during the 1990s and onward due to the high and fast foreign direct investments in ICT industries and their related services.

The second possible explanation is more theoretical and relies on the Kaldor's analysis. For Kaldor (1966) the Kaldor-Verdoorn Law is a statistical relation that illustrates the existence of increasing returns. These increasing returns can be static, in the sense that large scale production facilities are highly productive, or these can be dynamic. In this second case, increasing returns are rooted in the macro-division of labour, among sectors and countries, as developed by Youngs (1928).

Boyer and Petit (1981, 1991) justified the loss of significance of the Kaldor-Verdoorn Law by drastic structural changes as tertiarisation. For Kaldor, and followed by Boyer and Petit, increasing returns are mainly concentrated in manufacturing activities. The shift towards service activities in the most advanced economies corresponds also to a changes in the international specialisation patterns. The most advanced economies specialising in tertiary activities, peripheral economies specialised in manufacturing activities. The sources of increasing returns moved from the most advanced economies to peripheral countries. Some of these latter being included in our enlarged sample, we might then explain the fact that then law holds by these changes.

3.1.3 Extending the estimation to non Pre-1974 OECD members

This third set of estimations tests the Kaldor-Verdoorn Law using a sample extended to a selected number of Eastern European, Latin American and East Asian countries. These extensions are detailed in Table 3.10.

Table 3.10: Extended sample for the various periods

1950-1960	1960-1970	1970-1980	1980-1990	1990-2000
OECD sample	OECD sample	OECD sample	OECD sample	OECD sample
				Iceland*
				New Zealand*
U.S.S.R.	U.S.S.R.	U.S.S.R.	U.S.S.R.	
				Czech Republic
				Estonia
			Hungary	Hungary
				Latvia
				Lithuania
				Poland
				Slovakia
				Slovenia
	Argentina	Argentina	Argentina	Argentina
	Brazil	Brazil	Brazil	Brazil
	Chili	Chili	Chili	Chili
	Colombia	Colombia	Colombia	Colombia
	Mexico	Mexico	Mexico	Mexico
	Venezuela	Venezuela	Venezuela	Venezuela
Hong Kong	Hong Kong	Hong Kong	Hong Kong	Hong Kong
	Singapore	Singapore	Singapore	Singapore
		South Korea	South Korea	South Korea
	Taiwan	Taiwan	Taiwan	Taiwan
				Cyprus
				Malta

* pre-1974 OECD members not included in the *OECD sample*

In order to stress the specificific effect of these countries on the estimates of the law, we choose to introduce the following set of dummy variables:

- NOECD, this variable controls for non pre-1974 OECD members.

- EAST, controls for non pre-1974 OECD members from Central and Eastern Europe.

- LA, this variable controls for non pre-1974 OECD members from Latin America.

- ASIA, controls for non pre-1974 OECD members from Asia.

We then alternatively estimate the two specification of the Kaldor-Verdoorn Law, without dummies, then using only the NOECD dummy, and finally differentiating the non pre-1974 OECD members using the regional dummies.

We first estimate the Verdoorn specification of the law. Figure 3.5 presents labour productivity growth rates ploted against GDP growth rates for the five decades considered. Given the introduction of the dummy variables, we consecutively estimates the following three versions of this specification of the law:

$$\begin{aligned} &p = a_1 + a_2 y \\ &p = a_1 + a_2 y + a_3 NOECD \\ &p = a_1 + a_2 y + a_4 LA + a_5 ASIA + a_6 EAST \end{aligned} \tag{3.3}$$

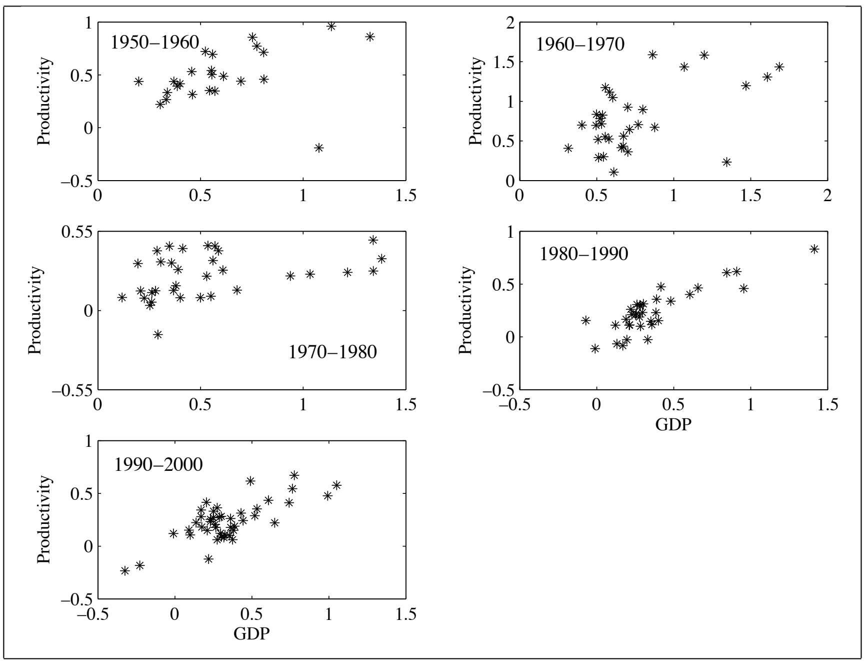

Figure 3.5: Labour productivity vs. GDP decades growth rates (*Entire sample)*

We used the ordinary least square methode to estimate the three relationship for each time period. The results of these estimations are presented in Table 3.11.

The main result coming out from these estimations for almost all periods (1960-1970, 1970-1980, 1980-1990 and 1990-2000), the Kaldor-Verdoorn Law holds for all the specification, including the dummy variables or the alternative one. For the 50s, the estimated value for the Verdoorn coefficient appears not significant when the relationship is estimated without the dummy variable for the non pre-1974 OECD members. Once the dummy is introduced, the Kaldor-Verdoorn Law holds, the coefficient being significantly different from zero. Moreover its value, appears to be slightly smaller than the estimates using the *Kaldor sample* and the *OECD sample*.

For all the periods until the 90s, the estimated value for the Verdoorn coefficient are similar to the estimated values realised with the two other samples, when the dummy variables are introduced. In other words, the enlargement to non OECD members does not seem to affect the value of the Verdoorn parameter.

Table 3.11: Estimates for the Verdoorn specification (*Entire sample*)

	a_1	a_2	a_3	a_4	a_5	a_6	R^2	R_c^2	F
1950-1960	0.2947	0.3302					0.1356	0.0963	3.4508
	(2.4964)	(1.8576)							
	0.2341	0.5071	-0.5592				0.4985	0.4507	12.0944
	(2.5078)	(3.4777)	(-3.8981)						
1960-1970	0.3227	0.6062					0.2724	0.2482	11.2328
	(2.1513)	(3.3515)							
	0.3264	0.7729	-0.4146				0.485	0.4495	22.7334
	(2.5427)	(4.7680)	(-3.4598)						
	0.1977	0.9457		-0.3700	-0.6614		0.485	0.4495	22.7334
	(1.2279)	(4.3496)		(-2.6799)	(-2.5782)				
1970-1980	0.1530	0.1580					0.1337	0.1058	4.7852
	(3.3025)	(2.1875)							
	0.1371	0.3169	-0.2083				0.4188	0.3801	18.8334
	(3.5329)	(4.3397)	(-3.8363)						
	0.1166	0.3491		-0.2103	-0.2309		0.3794	0.3152	8.2354
	(2.1432)	(2.8697)		(-3.3578)	(-1.7428)				
1980-1990	0.0176	0.6011					0.7180	0.7092	81.4619
	(0.5640)	(9.0256)							
	0.0432	0.6382	-0.1112				0.7826	0.7686	110.714
	(1.4808)	(10.5221)	(-3.0355)						
	0.0761	0.5376		-0.2116	-0.0011	0.0433	0.8719	0.8543	29.6023
	(2.0830)	(5.4408)		(-5.4880)	(-0.0141)	(0.6578)			
1990-2000	0.0549	0.5308					0.5564	0.5458	52.6726
	(1.7471)	(7.2576)							
	0.0475	0.5288	0.0177				0.5586	0.5371	51.1200
	(1.3353)	(7.1498)	(0.4564)						
	0.0146	0.6338		-0.1363	-0.0024	0.1314	0.6993	0.6685	59.8968
	(0.4141)	(7.7393)		(-2.7778)	(-0.0360)	(2.6988)			

For all the periods considered until the 90s, the dummy variable for non OECD members is significant. When considering the geographical dummies, two results are highlighted by the estimations: The dummy for Latin American countries appears to be significant for all the time periods, from the 60s to the 90s. On the contrary, the dummy for South East Asian country only appears significantly different from zero for the 60s.

From 1990 on, the estimated value of the Verdoorn coefficient is higher than the value estimated on the two previous samples. The enlargement of the sample to non pre-1974 OECD members, seems to affect significantly the estimates of the Verdoorn coefficient. Moreover, the coefficients estimated for the regional dummy variables appear significant and respectively negative for Latin Amercan countries and positive for Eastern European countries.

We then estimate the Kaldor specification of the law. Figure 3.6 presents employment growth rates plotted against GDP growth rates for the five decades considered.

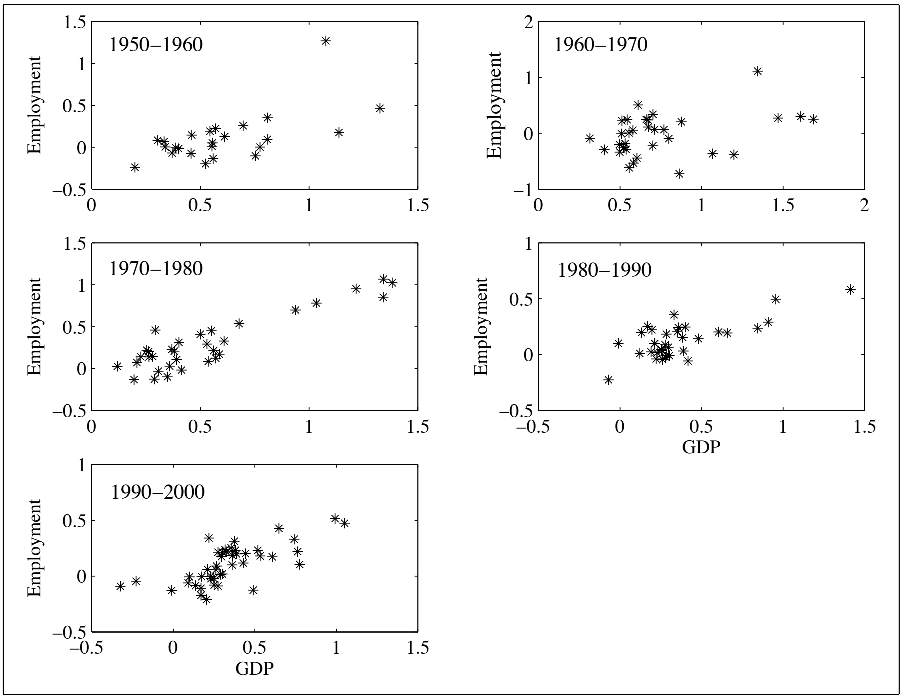

Figure 3.6: Employment vs. GDP decades growth rates (*Entire sample)*

Given the introduction of the dummy variables, we consecutively estimates the following three versions of this specification of the law:

$$\begin{aligned} e &= b_1 + b_2 y \\ e &= b_1 + b_2 y + b_3 NOECD \\ e &= b_1 + b_2 y + b_4 LA + b_5 ASIA + b_6 EAST \end{aligned} \tag{3.4}$$

We used the ordinary least square methode to estimate the three relationships for each time period. The results of these estimations are presented in Table 3.12.

The Kaldor's specification of the relationship confirms the results found previously. The estimates are such that the law holds for every time periods, when the dummy variables are included into the estimation. The estimated value for the coefficient b_2 appears to be significantly different from zero for all the periods except 1960-1970, and significantly lower then one for all the time periods when the dummy is included. For the 60s, the fact that b_2 appears not significantly different from zero is mechanically due to the fact that the estimated value of a_2 tends to one.

The main results of the estimation realised using the extended sample of countries can be summarised as follows:

Result 3 *Enlarging the sample used to estimate the Kaldor-Verdoorn Law to a selected numbers of Eastern European, Latin American and South East Asian countries, confirms that the Law holds at the macro-economic level. The estimated value of the Verdoorn coefficients appears similar to the one estimated. The dummy for the non pre-1974 OECD countries appears to be significant until the 90s. The dummy for Latin American countries remains significant over time, while for South East Asian it appears insignificant from the 70s on.*

In this third case, the results can be explained in two ways: First, once again we can refer to Rowthorn (1975) 's critic. The estimations can be sensitive to the existence of outliers. In this case, the existence of an outlier point (Hong Kong) explains why the estimated values for the period 1950-1960 are not significant. This problem is however accounted for with the introduction of the dummy variables.

The second explanation relies on the dynamic increasing returns. For Kaldor (1966), relying on Young (1928), the dynamic increasing returns are linked to the division of labour across sectors. In this case again, the results can then be explained by the international division of labour and the reallocation of manufacturing activities to peripheral countries. The fact that the dummy for South Asian countries is not significantly different from zero from the 70s onwards might confirms this interpretation.

Table 3.12: Estimates for the Kaldor specification (*Entire sample*)

	b_1	b_2	b_3	b_4	b_5	b_6	R^2	R^2_c	F
1950-1960	-0.2947	0.6698					0.3923	0.3647	11.4280
	(-2.4964)	(3.7688)							
	-0.2341	0.4929	0.5592				0.6474	0.6139	14.2035
	(-2.5078)	(3.3805)	(3.8981)						
1960-1970	-0.3227	0.3938					0.1364	0.1076	4.7397
	(-2.1513)	(2.1771)							
	-0.3264	0.2271	0.4146				0.3887	0.3466	1.9628
	(-2.5427)	(1.4010)	(3.4598)						
	-0.1977	0.0543		0.3700	0.6614		0.4055	0.3418	0.0623
	(-1.2279)	(0.2496)		(2.6799)	(2.5782)				
1970-1980	-0.1530	0.8420					0.8143	0.8083	135.9016
	(-3.3025)	(11.6577)							
	-0.1371	0.6831	0.2083				0.8754	0.8671	87.5185
	(-3.5329)	(9.3551)	(3.8363)						
	-0.1166	0.6509		0.2103	0.2309		0.8669	0.8532	28.6416
	(-2.1432)	(5.3518)		(3.3578)	(1.7428)				
1980-1990	-0.0176	0.3989					0.5286	0.5139	35.8855
	(-0.5640)	(5.9905)							
	-0.0432	0.3618	0.1112				0.6366	0.6132	35.5937
	(-1.4808)	(5.9660)	(3.0355)						
	-0.0761	0.4624		0.2116	0.0011	-0.0433	0.7860	0.7564	21.8919
	(-2.0830)	(4.6789)		(5.4880)	(0.0141)	(-0.6578)			
1990-2000	-0.0549	0.4692					0.4949	0.4829	41.1536
	(-1.7471)	(6.4151)							
	-0.0475	0.4712	-0.0177				0.4975	0.4730	40.5792
	(-1.3353)	(6.3702)	(0.4564)						
	-0.0146	0.3662		0.1363	0.0024	-0.1314	0.6577	0.6225	19.9961
	(-0.4141)	(4.4717)		(2.7778)	(0.0360)	(-2.6988)			

To sum up the findings of the macro-level estimations of the Kaldor-Verdoorn Law. We can stress that if the Law does hold after 1970 when estimated for a restricted sample of advanced economies, the latter is verified when estimated on the extended versions of the sample. This result can find an explanation in the drastic changes in the structures of the most advanced economies after 1970 and in the international reallocation of manufacturing activities. The sources of increasing returns have then migrated to peripheral countries.

3.2 A sectoral approach to the Kaldor-Verdoorn Law.

The second section of this chapter proposes to estimate the Kaldor-Verdoorn Law at the sectoral level. We use cross-country estimations for a selected number of sectors over two periods, 1980-1990 and 1990-2000. Our sample includes 16 countries namely: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK and USA. We use this sample of countries to estimated the Kaldor-Verdoorn Law for the 56 sectors detailed in Table 3.13.

As in the previous section we estimate the Kaldor-Verdoorn Law using the specifications:

- the Verdoorn specification:

$$p = a_1 + a_2 y$$

- the Kaldor specification:

$$e = b_1 + b_2 y$$

where p, e, and y, respectively represents the growth rates of labour productivity, employment, and real GDP.

Our data-set is built upon the October 2003, "Groningen Growth and Development Center, 60-Industry Database"[5]. More specifically, we rely on the "1995 constant prices value added" and the "Total employment in hours" series for the period 1979 to 2000 to compute the sector's gross output, employment and labour productivity growth rates. The detailed data-set can be found in appendix. We choose to estimate the Kaldor-Verdoorn Law using the decades' growth rates. These are computed as the growth rates between the average values over the two initial and the average over the two last years of a given decade.

[5] The database is available at http://www.ggdc.net

Table 3.13: List of sectors

1	Agriculture	31	Furniture, miscellaneous manufacturing; recycling
2	Forestry	32	Electricity, gas and water supply
3	Fishing	33	Construction
4	Mining and quarrying	34	Sale, maintenance, repair of motor vehicles; retail sale of automotive fuel
5	Food, drink & tobacco	35	Wholesale trade and commission trade, except of motor vehicles and motorcycles
6	Textiles	36	Retail trade, except of motor vehicles; repair of personal and household goods
7	Clothing	37	Hotels & catering
8	Leather and footwear	38	Inland transport
9	Wood & products of wood and cork	39	Water transport
10	Pulp, paper & paper products	40	Air transport
11	Printing & publishing	41	Supporting and auxiliary transport activities; travel agencies
12	Mineral oil refining, coke & nuclear fuel	42	Communications
13	Chemicals	43	Financial intermediation, except insurance and pension funding
14	Rubber & plastics	44	Insurance and pension funding, except compulsory social security
15	Non-metallic mineral products	45	Activities auxiliary to financial intermediation
16	Basic metals	46	Real estate activities
17	Fabricated metal products	47	Renting of machinery and equipment
18	Mechanical engineering	48	Computer and related activities
19	Office machinery	49	Research and development
20	Insulated wire	50	Legal, technical and advertising
21	Other electrical machinery and apparatus nec	51	Other business activities, nec
22	Electronic valves and tubes	52	Public administration and defence; compulsory social security
23	Telecommunication equipment	53	Education
24	Radio and television receivers	54	Health and social work
25	Scientific instruments	55	Other community, social and personal services
26	Other instruments	56	Private households with employed persons
27	Motor vehicles		
28	Building and repairing of ships and boats		
29	Aircraft and spacecraft		
30	Railroad equipment and transport equipment nec		

We choose to realise these estimations , first, to test its reliability at the meso-level. Second, we aim to see whether the assertion made on the effect of structural change on the macro-estimates can be confirmed by the sectoral level analysis. Finally we aim to stress the possible changes in the estimates arising from one period to the other.

This section is organised as follows. We first present the results from the sectoral level stimations for the period 1980-1990. We then present the results of the estimates for the 90s and stress the possible changes between the two periods.

3.2.1 Sectoral estimations of the Kaldor-Verdoorn Law: 1980-1990

The first set of estimations test the Kaldor-Verdoorn Law for the 56 sectors over the period 1980-1990. As a reference point, we estimated the two specifications of the law at the aggregate level for the same period. We then compare the estimated values of the coefficients for the sectors to the ones for the aggregated level.

Table 3.14: Kaldor-Verdoorn Law estimates (All Industry) 1980-1990

a_1	a_2	R^2	R_c^2	F
0.0547 (0.6205)	0.8453 (5.0860)	0.6488	0.6238	25.8675
b_1	b_2	R^2	R_c^2	F
-0.0345 (-0.6205)	0.1547 (0.9308)	0.0583	-0.0090	0.8663
Sample size : 16				

The estimations show that the law holds. As the estimated value for the Verdoorn coefficient, equal to 0.8453, appears significantly different from zero. The R^2 is about 0.65. The estimated value for b_2 is significantly lower than one, but not significantly different from zero. This is mechanically due to the fact that the estimated value for a_2 tends to one. This tend to show a high level of increasing returns.

We then estimate the Verdoorn specification of the law for each of the 56 sectors. The outcome of these estimations is detailed in Table 3.15. The main result is that the value of the Verdoorn coefficient is significantly different from zero for most of the sectors (52 out of 56 sectors). The Kaldor-Verdoorn Law therefore holds for most of the sectors. The estimations moreover show that for a large number of sectors, the estimated values for the Verdoorn coefficient tend to one.

Table 3.15: Sectoral estimations of Verdoorn's specification (1980-1990)

Sect.	a_1		a_2		R^2	R_c^2	F	Sect.	a_1		a_2		R^2	R_c^2	F
1	0.3157	(5.8906)	0.6603	(3.7510)	0.5012	0.4656	14.0700	29	0.1862	(1.5473)	0.5897	(7.2953)	0.8037	0.7886	53.2214
2	0.1955	(4.1215)	1.0174	(12.6335)	0.9247	0.9189	159.6041	30	0.2981	(3.9112)	0.4510	(6.3404)	0.7417	0.7233	40.2012
3	0.0737	(0.7032)	0.9448	(2.9513)	0.3835	0.3395	8.7101	31	0.1602	(4.4019)	0.5729	(3.7933)	0.5068	0.4716	14.3888
4	0.2755	(4.7787)	0.8619	(10.4398)	0.8862	0.8780	108.9891	32	0.0115	(0.1914)	0.9064	(6.3033)	0.7394	0.7208	39.7314
5	0.0937	(3.3358)	1.0529	(13.4085)	0.9278	0.9226	179.7884	33	0.1446	(4.4258)	0.3809	(3.2384)	0.4283	0.3874	10.4871
6	0.3001	(8.1922)	1.0406	(5.8636)	0.7106	0.6900	34.3822	34	0.0320	(0.6121)	0.5574	(3.7634)	0.5029	0.4674	14.1632
7	0.2724	(8.2708)	0.7119	(51.8200)	0.9948	0.9944	2685.3	35	-0.0924	(-1.6316)	1.0491	(7.4352)	0.7979	0.7835	55.2823
8	0.2737	(8.8987)	0.3232	(3.5709)	0.4952	0.4563	12.7510	36	0.0358	(0.8295)	0.7358	(5.5903)	0.6906	0.6685	31.2519
9	0.1405	(3.6053)	0.9586	(8.1278)	0.8251	0.8126	66.0617	37	-0.1840	(-3.5981)	0.9227	(4.3908)	0.5793	0.5493	19.2788
10	0.1269	(1.9353)	0.9575	(5.4773)	0.6818	0.6591	30.0009	38	0.0749	(1.6384)	0.8074	(7.0541)	0.7804	0.7647	49.7606
11	-0.0304	(-0.6789)	1.0281	(10.0726)	0.8787	0.8701	101.4577	39	0.2058	(3.7556)	0.9300	(20.2830)	0.9671	0.9647	411.407
12	0.1210	(2.0918)	0.8156	(9.8949)	0.8828	0.8738	97.9088	40	0.0823	(0.7293)	0.6558	(4.6064)	0.6201	0.5909	21.2187
13	0.0799	(1.8074)	0.9427	(18.2651)	0.9597	0.9568	333.6127	41	0.0170	(0.1687)	0.7384	(3.8294)	0.5116	0.4767	14.6639
14	0.0342	(0.6394)	0.8939	(11.3873)	0.9026	0.8956	129.6696	42	0.0036	(0.0709)	0.9378	(15.2786)	0.9434	0.9394	233.43
15	0.2303	(5.2618)	0.7366	(6.2304)	0.7349	0.7160	38.8184	43	-0.2512	(-2.7669)	1.0497	(7.3019)	0.7920	0.7772	53.3174
16	0.2701	(6.1470)	0.9414	(8.8377)	0.8480	0.8371	78.1046	44	-0.1565	(-2.3847)	0.9690	(8.8500)	0.8484	0.8375	78.3228
17	0.1570	(5.0459)	0.8379	(6.9374)	0.7747	0.7586	48.1271	45	-0.5634	(-2.4826)	1.1697	(3.3074)	0.4769	0.4333	10.9389
18	0.1220	(5.0273)	0.8619	(13.4270)	0.9279	0.9228	180.2840	46	-0.3457	(-1.7614)	0.8367	(1.7307)	0.1762	0.1174	2.9953
19	0.2415	(2.0951)	0.9813	(183.5805)	0.9996	0.9996	33702	47	-0.4202	(-2.7118)	0.9876	(5.2760)	0.6654	0.6415	27.8358
20	0.2337	(3.8515)	0.7495	(38.4325)	0.9906	0.9899	14771	48	-0.4182	(-3.7841)	0.6604	(9.5003)	0.8657	0.8561	90.2565
21	0.1417	(2.4265)	0.6604	(24.7088)	0.9776	0.9760	610.5271	49	-0.1357	(-0.8687)	0.5850	(2.2522)	0.2660	0.2135	5.0726
22	0.3712	(4.4121)	0.9525	(108.6485)	0.9995	0.9988	11804	50	-0.5379	(-1.6705)	1.0061	(1.8706)	0.2000	0.1428	3.4993
23	0.3735	(5.6811)	0.9547	(124.7565)	0.9992	0.9991	15564	51	-0.1660	(-1.0652)	0.3017	(1.2748)	0.1040	0.0400	1.6251
24	0.3384	(6.0951)	0.9124	(65.0790)	0.9969	0.9967	4235.3	52	-0.0724	(-1.0658)	0.8346	(4.4354)	0.5842	0.5545	19.6730
25	0.1353	(2.2235)	0.7701	(10.8450)	0.8936	0.8860	117.6149	53	-0.0889	(-1.5370)	0.7082	(3.4798)	0.4638	0.4255	12.109
26	0.1606	(2.6767)	0.8282	(10.1816)	0.8810	0.8725	103.6643	54	-0.2688	(-4.4028)	1.0545	(8.0021)	0.8206	0.8078	64.0341
27	0.1604	(2.1908)	0.6134	(4.4196)	0.5825	0.5527	19.5331	55	-0.2919	(-3.5981)	1.1813	(5.2541)	0.6635	0.6395	27.6060
28	0.2776	(4.0913)	0.4640	(6.9621)	0.7759	0.7599	48.4706	56	-0.0752	(-0.5830)	-0.0965	(-0.2293)	0.0052	-0.0942	0.0526

Table 3.16: Sectoral estimations of Kaldor's specification (1980-1990)

Sect.	b_1		b_2		R^2	R^2_c	F	Sect.	b_1		b_2		R^2	R^2_c	F
1	-0.3157	(-5.8906)	0.3397	(1.9300)	0.2101	0.1537	3.7248	29	-0.1862	(-1.5473)	0.4103	(5.0760)	0.6647	0.6389	25.7662
2	-0.1955	(-4.1215)	-0.0174	(-0.2155)	0.0036	-0.0731	0.0464	30	-0.2981	(-3.9112)	0.5490	(7.7184)	0.8097	0.7961	59.5742
3	-0.0737	(-0.7032)	0.0552	(0.1723)	0.0021	-0.0692	0.0297	31	-0.1602	(-4.4019)	0.4271	(2.8284)	0.3636	0.3182	7.9998
4	-0.2755	(-4.7787)	0.1381	(1.6730)	0.1666	0.1071	2.7988	32	-0.0115	(-0.1914)	0.0936	(0.6510)	0.0294	-0.0400	0.4237
5	-0.0937	(-3.3358)	-0.0529	(-0.6737)	0.0314	-0.0378	0.4539	33	-0.1446	(-4.4258)	0.6191	(5.2625)	0.6642	0.6402	27.6934
6	-0.3001	(-8.1922)	-0.0406	(-0.2287)	0.0037	-0.0674	0.0523	34	-0.0320	(-0.6121)	0.4426	(2.9883)	0.3894	0.3458	8.9300
7	-0.2724	(-8.2708)	0.2881	(20.9667)	0.9691	0.9669	439.6007	35	0.0924	(1.6316)	-0.0491	(-0.3480)	0.0086	-0.0622	0.1211
8	-0.2737	(-8.8987)	0.6768	(7.4779)	0.8114	0.7969	55.9188	36	-0.0358	(-0.8295)	0.2642	(2.0075)	0.2235	0.1681	4.0301
9	-0.1405	(-3.6053)	0.0414	(0.3507)	0.0087	-0.0621	0.1230	37	0.1840	(3.5981)	0.0773	(0.3681)	0.0096	-0.0612	0.1355
10	-0.1269	(-1.9353)	0.0425	(0.2431)	0.0042	-0.0669	0.0591	38	-0.0749	(-1.6384)	0.1926	(1.6823)	0.1682	0.1087	2.8303
11	0.0304	(0.6789)	-0.0281	(-0.2748)	0.0054	-0.0657	0.0755	39	-0.2058	(-3.7556)	0.0700	(1.5263)	0.1427	0.0814	2.3295
12	-0.1210	(-2.0918)	0.1844	(2.2371)	0.2780	0.2224	5.0045	40	-0.0823	(-0.7293)	0.3442	(2.4174)	0.3101	0.2571	5.8439
13	-0.0799	(-1.8074)	0.0573	(1.1092)	0.0808	0.0151	1.2303	41	-0.0170	(-0.1687)	0.2616	(1.3569)	0.1162	0.0531	1.8412
14	-0.0342	(-0.6394)	0.1061	(1.3517)	0.1154	0.0523	1.8272	42	-0.0036	(-0.0709)	0.0622	(1.0127)	0.0683	0.0017	1.0256
15	-0.2303	(-5.2618)	0.2634	(2.2278)	0.2617	0.2090	4.9630	43	0.2512	(2.7669)	-0.0497	(-0.3457)	0.0085	-0.0624	0.1195
16	-0.2701	(-6.1470)	0.0586	(0.5500)	0.0212	-0.0488	0.3025	44	0.1565	(2.3847)	0.0310	(0.2829)	0.0057	-0.0653	0.0800
17	-0.1570	(-5.0459)	0.3301	(3.4191)	0.4550	0.4161	11.6900	45	0.5634	(2.4826)	-0.1697	(-0.4798)	0.0188	-0.0629	0.2302
18	-0.1220	(-5.0273)	0.1621	(2.5982)	0.3253	0.2771	6.7509	46	0.3457	(1.7614)	0.1633	(0.3378)	0.0081	-0.0628	0.1141
19	-0.2415	(-2.0951)	0.0187	(3.5022)	0.4670	0.4289	12.2656	47	0.4202	(2.7118)	0.0124	(0.0663)	0.0003	-0.0711	0.0044
20	-0.2337	(-3.8515)	0.2505	(12.8435)	0.9218	0.9162	164.9565	48	0.4182	(3.7841)	0.3396	(4.8852)	0.6303	0.6039	23.8652
21	-0.1417	(-2.4265)	0.3396	(12.7058)	0.9202	0.9145	161.4366	49	0.1357	(0.8687)	0.4150	(1.5977)	0.1542	0.0938	2.5526
22	-0.3712	(-4.4121)	0.0475	(5.4238)	0.6935	0.6700	29.4178	50	0.5379	(1.6705)	-0.0061	(-0.0114)	0.0000	-0.0714	0.0001
23	-0.3735	(-5.6811)	0.0453	(5.9264)	0.7299	0.7091	35.1225	51	0.1660	(1.0652)	0.6983	(2.9507)	0.3834	0.3394	8.7067
24	-0.3384	(-6.0951)	0.0876	(6.2480)	0.7502	0.7310	39.0378	52	0.0724	(1.0658)	0.1654	(0.8789)	0.0523	-0.0154	0.7725
25	-0.1353	(-2.2235)	0.2299	(3.2385)	0.4283	0.3874	10.4876	53	0.0889	(1.5370)	0.2918	(1.4335)	0.1280	0.0657	2.0550
26	-0.1606	(-2.6767)	0.1718	(2.1120)	0.2416	0.1875	4.4605	54	0.2688	(4.4028)	-0.0545	(-0.4136)	0.0121	-0.0585	0.1711
27	-0.1604	(-2.1908)	0.3866	(2.7856)	0.3566	0.3106	7.7596	55	0.2919	(3.5981)	-0.1813	(-0.8063)	0.0444	-0.0239	0.6501
28	-0.2776	(-4.0913)	0.5360	(8.0432)	0.8221	0.8094	64.6938	56	0.0752	(0.5830)	1.0965	(2.6050)	0.4043	0.3447	6.786

Table 3.17: T-test for b_2=1 (1980-1990)

Sector	t	Sector	t
1	-3.7510	29	-7.2953
2	-12.6335	30	-6.3404
3	-2.9513	31	-3.7933
4	-10.4398	32	-6.3033
5	-13.4085	33	-3.2384
6	-5.8636	34	-3.7634
7	-51.8200	35	-7.4352
8	-3.5709	36	-5.5903
9	-8.1278	37	-4.3908
10	-5.4773	38	-7.0541
11	-10.0726	39	-20.2830
12	-9.8949	40	-4.6064
13	-18.2651	41	-3.8294
14	-11.3873	42	-15.2786
15	-6.2304	43	-7.3019
16	-8.8377	44	-8.8500
17	-6.9374	45	-3.3074
18	-13.4270	46	-1.7307
19	-183.5805	47	-5.2760
20	-38.4325	48	-9.5003
21	-24.7088	49	-2.2522
22	-108.6485	50	-1.8706
23	-124.7565	51	-1.2748
24	-65.0790	52	-4.4354
25	-10.8450	53	-3.4798
26	-10.1816	54	-8.0021
27	-4.4196	55	-5.2541
28	-6.9621	56	0.2293

The law is not verified for only four sectors:

- Real estate activities,

- Legal, technical and advertising activities,

- Other business activities (other then 42 to 50),

- Private households with employed persons activities.

These results are confirmed by the estimations of the Kaldor specification of the law as presented in Tables 3.16 and 3.17. For most of the sectors, the estimated value for b_2 are significantly lower then one (Table 3.16). Moreover, for a large number of sector b_2 is not significantly different from zero. These corresponds to the high value estimated for the Verdoorn coefficient.

Finally for the four sectors, the estimation for the Kaldor specification shows the following result. The estimate for b_2 appears significantly positive but not significantly different from one, only for the "Other business activities (other then 42 to 50)" and the "Private households with employed persons activities". In other words, the Law does not hold for these two sectors because these are characterised by constant returns to scale. For the "Real estate activities" and the "Legal, technical and advertising" sectors, the estimation of the Law exhibits simultaneously that a_2 and b_2 are non significantly different from zero. For these sectors, no clear relationship between employment, productivity and gross output seems to occur.

We then revert to a T-test to compare the estimated values of the Verdoorn coefficient for each sector to its estimated value for the aggregate level ('All industry'). The results of this test are detailed in Table 3.18. For most of the sectors, the estimated Verdoorn coefficient is not significantly different from the aggregate one.

However, for the following sectors the estimated value of the coefficient appears to be significantly bigger then for the aggregate:

- Forestry,
- Food, drinks and tobacco,
- Office machinery,
- Electronic valves and tubes,
- Telecom equipment,
- Radio and TV receivers.

Among these sectors, four corresponds to electronics and manufacturing directly applied to the Information and communication technologies (ICTs).

The following sectors, for which the law holds, show an estimated value for a_2 significantly lower then the aggregate one. Most of these are traditional manufacturing activities:

- Clothing,
- Leather and footwear,
- Insulated wire,

Table 3.18: T-test: Sector's estimates differences with 'All Industry' (1980-1990)

Sector	t-values		Sector	t-values	
	a_1	a_2		a_1	a_2
1	5.2472	-1.0512	29	1.2607	-3.1622
2	3.3947	2.1365	30	3.4589	-5.5436
3	0.3741	0.3109	31	3.4544	-1.8040
4	4.1807	0.2008	32	-0.3842	0.4248
5	2.1083	2.6437	33	3.3705	-3.9474
6	7.2511	1.1004	34	-0.0468	-1.9438
7	7.2238	-9.7069	35	-2.2401	1.4444
8	7.7776	-5.7687	36	0.0301	-0.8321
9	2.7205	0.9609	37	-4.2725	0.3681
10	1.4096	0.6418	38	0.8847	-0.3308
11	-1.4485	1.7905	39	3.1263	1.8475
12	1.4958	-0.3603	40	0.4239	-1.3309
13	1.0273	1.8879	41	-0.1728	-0.5546
14	-0.0059	0.6189	42	-0.6174	1.5075
15	4.474	-0.9193	43	-3.1466	1.4218
16	5.3624	0.9022	44	-2.9099	1.1299
17	3.9375	-1.8170	45	-2.6345	0.9173
18	3.607	-0.1192	46	-1.9371	-0.0178
19	1.7959	25.4387	47	-2.9343	0.7602
20	3.2832	-4.9113	48	-4.0961	-2.6598
21	1.836	-6.9179	49	-1.0895	-1.0021
22	4.0023	12.2227	50	-1.7776	0.299
23	5.1567	14.2897	51	-1.2864	-2.2970
24	5.4741	4.786	52	-1.5730	-0.0568
25	1.657	-1.0598	53	-2.1334	-0.6735
26	2.102	-0.2102	54	-4.9676	1.5875
27	1.7198	-1.6710	55	-4.0231	1.4943
28	3.5832	-5.7220	56	-0.8503	-2.2375

- Other electrical machinery and apparatus (other the 19 and 20),
- Building and repairing of ships and boats,
- Aircraft and spacecraft,
- Railroad equipment and transport equipment,
- Construction,
- Sale, maintenance and repair of motor vehicles,
- Computer and related activities.

The results of the sectoral estimations of the Kaldor-Verdoorn Law for the period 1980-1990 can be summarised as follows:

Result 4 *The estimations realised for the 56 sectors for the 80s show that the Kaldor-Verdoorn Law holds for most of the sectors. Moreover the increasing returns appear relatively high (close to one). The estimations also show that for ICT related manufacturing sectors, the increasing returns are higher than the aggregate level for this period. These increasing returns appear lower than the aggregate for a selected number of traditional manufacturing activities.*

These results can be paradoxical with respect to Kaldor's analysis. For Kaldor (1966), increasing returns appearing at the aggregate level are largely due to the manufacturing sectors. These then generate the necessary resources to trigger the other sectors. Our estimates for the 80s, however, tend to show that increasing returns appear not only in manufacturing activities but also in primary and services sectors. The existence of increasing returns in service sectors might be rooted in the development and the adoption of ICTs over the last two decades. This fact as been pointed out among others by Cainelli, Evangelista and Savona (2005). Moreover, our analysis shows on the one hand that traditional manufacturing sectors exhibit increasing returns significantly lower than the average. On the other hand the estimations highlighted the fact that the ICT related manufacturing activities exhibit higher increasing returns than the average.

3.2.2 Sectoral estimations of the Kaldor-Verdoorn Law: 1990-2000

The second set of estimations test the Kaldor-Verdoorn Law for the 56 sectors over the period 1990-2000. Table 3.19 presents the estimation of the two specification of the Kaldor-Verdoorn Law for the aggregated level.

Table 3.19: Kaldor-Verdoorn Law estimates 1990-2000 (All Industry)

a_1	a_2	R^2	R_c^2	F
0.0210 (1.6093)	0.6701 (8.5359)	0.8388	0.8273	72.8615
b_1	b_2	R^2	R_c^2	F
-0.0547 (-1.6093)	0.3299 (4.2025)	0.5578	0.5262	17.6609
Sample size : 16				

The estimations show that the law holds. As the estimated value for the Verdoorn coefficient, equal to 0.6701 appears significantly different from zero. This estimated value is significantly lower then the one found for the 80s. The R^2, around 0.84, is on the other side higher than the one found for the 80s. The explanatory power of the law increased. The estimated value of b_2 is significantly lower than one, confirming the first result.

We then estimate the Verdoorn specification of the law for each of the 56 sectors. These are detailed in Table 3.20. As for the previous period, the estimates for 1990-2000 show that for a large number of sectors, 46 out of 56 sectors, the Kaldor-Verdoorn Law seems verified. For these 46 sectors, the estimated value of the Verdoorn coefficient appears significantly different from zero. The nature of these 46 sectors is heterogeneous, and counts primary, manufacturing as well as service activities. The existence of increasing returns is, thus, not limited to the manufacturing sectors. These sectors where the law holds, also show a regain in the robustness of the law. For these sectors the value of the R^2 are generally higher than for the 80s.

Among the sectors where the Kaldor-Verdoorn Law is not verified, we count the same four services activities already pointed out in the estimates for the 80s, namely:

- Real estate activities,
- Legal, technical and advertising activities,
- Other business activities (other then 42 to 50),
- Private households with employed persons activities.

For three other service sectors, the estimates appears non-significant for the 90s while it was in the 80s:

- Retail trade and repair of personal and households goods (except of motor vehicles),
- Hotels and catering,
- Computer and related activities.

Table 3.20: Sectoral estimations of the Verdoorn specification (1990-2000)

Sect.	a_1		a_2		R^2	R^2_c	F	Sect.	a_1		a_2		R^2	R^2_c	F
1	0.2842	(8.1319)	0.8906	(9.0770)	0.8548	0.8444	82.3924	29	-0.0681	(-0.2414)	0.4642	(1.5127)	0.1497	0.0843	2.2881
2	0.2516	(4.1785)	0.9453	(30.8546)	0.9855	0.9845	952.008	30	0.1448	(1.0832)	0.7211	(7.1145)	0.7833	0.7679	50.615
3	0.1887	(3.8328)	1.0272	(4.6142)	0.6033	0.5750	21.2912	31	0.1106	(3.6633)	0.7407	(13.9275)	0.9327	0.9279	193.975
4	0.3402	(6.6739)	0.7899	(9.4782)	0.8652	0.8555	89.8359	32	0.1699	(2.1946)	1.0186	(5.4170)	0.6770	0.6539	29.3436
5	0.0652	(2.3011)	1.1916	(7.5265)	0.8018	0.7877	56.6488	33	0.0242	(0.7499)	0.4549	(6.4970)	0.7509	0.7331	42.2110
6	0.3036	(10.8426)	0.7203	(25.8665)	0.9795	0.9780	669.075	34	-0.0543	(-1.0148)	0.9623	(5.3339)	0.6702	0.6466	28.4508
7	0.3782	(6.2891)	0.5547	(2.9828)	0.3886	0.3449	8.8970	35	-0.0365	(-0.7205)	0.8521	(8.0819)	0.8235	0.8109	65.3174
8	0.2814	(5.5771)	0.3732	(2.1469)	0.2617	0.2050	4.6092	36	0.1023	(1.5988)	0.3921	(2.0048)	0.2231	0.1676	4.0193
9	0.0995	(2.5910)	0.7267	(25.4410)	0.9788	0.9773	647.243	37	-0.0595	(-1.3257)	0.1159	(0.6479)	0.0291	-0.0402	0.4198
10	0.1347	(3.2067)	0.9160	(8.5434)	0.8391	0.8276	72.9896	38	0.1164	(1.4421)	0.7501	(5.7892)	0.7054	0.6843	33.5145
11	0.0822	(1.9390)	0.8510	(17.5466)	0.9565	0.9534	307.884	39	0.1887	(2.3641)	0.7561	(5.9260)	0.7150	0.6946	35.1174
12	0.1814	(4.0867)	1.0105	(100.8555)	0.0001	0.0001	1.0172	40	-0.0112	(-0.1607)	0.8675	(17.5264)	0.9594	0.9563	307.176
13	0.1176	(1.4935)	0.8630	(14.4380)	0.9371	0.9326	208.456	41	-0.2027	(-2.1403)	0.9492	(7.6676)	0.8077	0.7939	58.7923
14	-0.0248	(-0.5681)	0.9384	(9.6940)	0.8703	0.8611	93.9738	42	0.1321	(1.4316)	0.8731	(11.5504)	0.9050	0.8982	133.412
15	0.1619	(5.7144)	0.6398	(5.4941)	0.6831	0.6605	30.1848	43	0.1337	(2.1391)	0.5432	(5.3126)	0.6684	0.6448	28.2238
16	0.2160	(5.1447)	0.9990	(6.5714)	0.7552	0.7377	43.1831	44	-0.0478	(-0.7377)	0.8427	(7.1398)	0.7845	0.7691	50.9763
17	0.0979	(2.0835)	0.5893	(4.1624)	0.5531	0.5212	17.3252	45	-0.2033	(-1.3129)	0.6484	(5.7197)	0.7316	0.7093	32.7155
18	0.1105	(4.0578)	0.6300	(5.6948)	0.6985	0.6769	32.4306	46	-0.1758	(-1.2060)	0.5691	(1.5500)	0.1465	0.0855	2.4026
19	0.1212	(0.4777)	0.9971	(390.6071)	0.0000	0.0000	1.5257	47	-0.2858	(-2.2217)	0.8411	(11.0220)	0.8967	0.8893	121.484
20	0.2130	(2.3604)	0.3561	(2.2889)	0.2723	0.2203	5.2391	48	-0.0754	(-0.1786)	0.1902	(0.9608)	0.0619	-0.0051	0.9232
21	0.1643	(4.7909)	0.5744	(6.8778)	0.7716	0.7553	47.3044	49	-0.1536	(-1.4426)	0.8314	(28.3171)	0.9828	0.9816	801.856
22	0.0001	(0.0011)	0.0010	(2.5898)	0.0000	0.0000	6.7068	50	-0.2922	(-1.3026)	0.4399	(1.0168)	0.0688	0.0022	1.0338
23	0.0135	(0.1027)	0.6139	(11.3809)	0.9088	0.9018	129.525	51	-0.3087	(-1.1856)	0.3714	(1.0262)	0.0700	0.0035	1.0530
24	-0.2845	(-1.6279)	0.0093	(0.0300)	0.0001	-0.0768	0.0009	52	0.0202	(0.6161)	0.6253	(3.1948)	0.4216	0.3803	10.2066
25	-0.4750	(-2.7873)	-0.0014	(-0.0034)	0.0000	-0.0714	0.0000	53	-0.0863	(-2.3373)	0.8074	(8.9506)	0.8512	0.8406	80.1124
26	0.1171	(0.2990)	0.5452	(2.3555)	0.2838	0.2327	5.5482	54	-0.1164	(-3.5779)	0.7053	(10.3518)	0.8844	0.8762	107.159
27	0.1094	(1.7019)	0.9098	(14.2493)	0.9355	0.9309	203.042	55	-0.2544	(-2.7022)	1.1674	(3.5685)	0.4763	0.4389	12.7344
28	0.1891	(2.4239)	0.0678	(0.4098)	0.0119	-0.0587	0.1679	56	0.0189	(0.1764)	-0.1732	(-0.8658)	0.0697	-0.0233	0.7496

Table 3.21: Sectoral estimations of the Kaldor specification (1990-2000)

Sect.	a_1		a_2		R^2	R_c^2	F	Sect.	a_1		a_2		R^2	R_c^2	F
1	-0.2842	(-8.1319)	0.1094	(1.1156)	0.0816	0.0160	1.2445	29	0.0681	(0.2414)	0.5358	(1.7459)	0.1899	0.1276	3.0482
2	-0.2516	(-4.1785)	0.0547	(1.7871)	0.1858	0.1276	3.1938	30	-0.1448	(-1.0832)	0.2789	(2.7510)	0.3509	0.3045	7.5680
3	-0.1887	(-3.8328)	-0.0272	(-0.1220)	0.0011	-0.0703	0.0149	31	-0.1106	(-3.6633)	0.2593	(4.8758)	0.6294	0.6029	23.7731
4	-0.3402	(-6.6739)	0.2101	(2.5216)	0.3123	0.2632	6.3586	32	-0.1699	(-2.1946)	-0.0186	(-0.0987)	0.0007	-0.0707	0.0097
5	-0.0652	(-2.3011)	-0.1916	(-1.2104)	0.0947	0.0301	1.4651	33	-0.0242	(-0.7499)	0.5451	(7.7849)	0.8123	0.7989	60.6042
6	-0.3036	(-10.8426)	0.2797	(10.0420)	0.8781	0.8694	100.841	34	0.0543	(1.0148)	0.0377	(0.2089)	0.0031	-0.0681	0.0436
7	-0.3782	(-6.2891)	0.4453	(2.3944)	0.2905	0.2399	5.7330	35	0.0365	(0.7205)	0.1479	(1.4023)	0.1232	0.0605	1.9665
8	-0.2814	(-5.5771)	0.6268	(3.6051)	0.4999	0.4615	12.9966	36	-0.1023	(-1.5988)	0.6079	(3.1077)	0.4082	0.3660	9.6580
9	-0.0995	(-2.5910)	0.2733	(9.5664)	0.8673	0.8578	91.5162	37	0.0595	(1.3257)	0.8841	(4.9421)	0.6356	0.6096	24.4244
10	-0.1347	(-3.2067)	0.0840	(0.7832)	0.0420	-0.0265	0.6134	38	-0.1164	(-1.4421)	0.2499	(1.9282)	0.2098	0.1534	3.7181
11	-0.0822	(-1.9390)	0.1490	(3.0723)	0.4027	0.3600	9.4391	39	-0.1887	(-2.3641)	0.2439	(1.9117)	0.2070	0.1504	3.6546
12	-0.1814	(-4.0867)	-0.0105	(-1.0522)	0.0785	0.0076	1.1072	40	0.0112	(0.1607)	0.1325	(2.6780)	0.3555	0.3060	7.1719
13	-0.1176	(-1.4935)	0.1370	(2.2914)	0.2728	0.2208	5.2507	41	0.2027	(2.1403)	0.0508	(0.4100)	0.0119	-0.0587	0.1681
14	0.0248	(0.5681)	0.0616	(0.6360)	0.0281	-0.0413	0.4046	42	-0.1321	(-1.4316)	0.1269	(1.6783)	0.1675	0.1080	2.8166
15	-0.1619	(-5.7144)	0.3602	(3.0934)	0.4060	0.3636	9.5691	43	-0.1337	(-2.1391)	0.4568	(4.4682)	0.5878	0.5584	19.9653
16	-0.2160	(-5.1447)	0.0010	(0.0068)	0.0000	-0.0714	0.0000	44	0.0478	(0.7377)	0.1573	(1.3327)	0.1126	0.0492	1.7761
17	-0.0979	(-2.0835)	0.4107	(2.9003)	0.3753	0.3307	8.4117	45	0.2033	(1.3129)	0.3516	(3.1021)	0.4450	0.3988	9.6233
18	-0.1105	(-4.0578)	0.3700	(3.3440)	0.4441	0.4043	11.1823	46	0.1758	(1.2060)	0.4309	(1.1738)	0.0896	0.0246	1.3778
19	-0.1212	(-0.4777)	0.0029	(1.1434)	0.0854	0.0201	1.3073	47	0.2858	(2.2217)	0.1589	(2.0820)	0.2364	0.1819	4.3348
20	-0.2130	(-2.3604)	0.6439	(4.1383)	0.5502	0.5181	17.1259	48	0.0754	(0.1786)	0.8098	(4.0898)	0.5444	0.5118	16.7262
21	-0.1643	(-4.7909)	0.4256	(5.0957)	0.6497	0.6247	25.9661	49	0.1536	(1.4426)	0.1686	(5.7432)	0.7020	0.6807	32.9842
22	-0.1156	(-1.0581)	0.0031	(7.9947)	0.8310	0.8180	63.9160	50	0.2922	(1.3026)	0.5601	(1.2943)	0.1069	0.0431	1.6753
23	-0.0135	(-0.1027)	0.3861	(7.1592)	0.7977	0.7821	51.2538	51	0.3087	(1.1856)	0.6286	(1.7364)	0.1772	0.1184	3.0152
24	0.2845	(1.6279)	0.9907	(3.1988)	0.4404	0.3974	10.2320	52	-0.0202	(-0.6161)	0.3747	(1.9142)	0.2074	0.1508	3.6641
25	0.4750	(2.7873)	1.0014	(2.3975)	0.2911	0.2404	5.7479	53	0.0863	(2.3373)	0.1926	(2.1356)	0.2457	0.1919	4.5609
26	-0.1171	(-0.2990)	0.4548	(1.9651)	0.2162	0.1602	3.8615	54	0.1164	(3.5779)	0.2947	(4.3244)	0.5719	0.5413	18.7003
27	-0.1094	(-1.7019)	0.0902	(1.4121)	0.1247	0.0622	1.9941	55	0.2544	(2.7022)	-0.1674	(-0.5118)	0.0184	-0.0518	0.2619
28	-0.1891	(-2.4239)	0.9322	(5.6308)	0.6937	0.6718	31.7056	56	-0.0189	(-0.1764)	1.1732	(5.8655)	0.7748	0.7523	34.4041

Finally, in three manufacturing sectors the Kaldor-Verdoorn Law is not verified for the period 1990-2000:

- Radio and television receiver,

- Scientific instruments,

- Aircraft and spacecraft.

These results are confirmed by the estimation of the Kaldor specification of the Law for each of the 56 sectors. The outcome of these estimations is detailed in Tables 3.21 and 3.22. For the 46 out of 56 sectors, the estimated value for the coefficient a_2, is significantly lower then one (Table 3.22). These sectors therefore exhibit significant increasing returns. Note that for some of these sectors the estimated value for b_2 appears non-significantly different from zero. This, as for the estimates for the 80s, is due to the high value of the estimated Verdoorn coefficient. This therefore implies a high level of increasing returns (as a_2 tends to one and b_2 to zero).

Concerning the sectors for which the Law does not hold, one can note that for most of them the estimated value for b_2 is not significantly different from one. These sectors are the following:

- Radio and television receiver,

- Scientific instruments,

- Aircraft and spacecraft.

- Retail trade and repair of personal and households goods (except of motor vehicles),

- Hotels and catering,

- Computer and related activities.

- Private households with employed persons activities.

For these sectors the estimations for the period 1990-2000 show the existence of constant returns to scale. For the three remaining sectors, and as for the 1980-1990 estimations, the estimated values for a_2 and b_2 are not significantly different from zero. In other words, for these sectors, there is no relationship between GDP, employment and productivity growth rates.

We then revert to a T-test to highlight the differences between the estimated values of the Verdoorn coefficient of each sectors with the aggregate

Table 3.22: T-test for b_2=1 (1990-2000)

Sector	t	Sector	t
1	-9.0770	29	-1.5127
2	-30.8546	30	-7.1145
3	-4.6142	31	-13.9275
4	-9.4782	32	-5.4170
5	-7.5265	33	-6.4970
6	-25.8665	34	-5.3339
7	-2.9828	35	-8.0819
8	-2.1469	36	-2.0048
9	-25.4410	37	-0.6479
10	-8.5434	38	-5.7892
11	-17.5466	39	-5.9260
12	-100.8555	40	-17.5264
13	-14.4380	41	-7.6676
14	-9.6940	42	-11.5504
15	-5.4941	43	-5.3126
16	-6.5714	44	-7.1398
17	-4.1624	45	-5.7197
18	-5.6948	46	-1.5500
19	-390.6071	47	-11.0220
20	-2.2889	48	-0.9608
21	-6.8778	49	-28.3171
22	-2.5898	50	-1.0168
23	-11.3809	51	-1.0262
24	-0.0300	52	-3.1948
25	0.0034	53	-8.9506
26	-2.3555	54	-10.3518
27	-14.2493	55	-3.5685
28	-0.4098	56	0.8658

level ('All industry'). The results of this test are detailed in Table 3.23. For a large number of sectors (32 out of 56), the estimated Verdoorn coefficient is not significantly different from the aggregate one.

However for 17 sectors out of the 56 sectors considered, the estimated value of the Verdoorn coefficient is significantly higher than the aggregated one. For the following sectors, the increasing returns thus appear significantly higher than the average:

- Agriculture,

- Forestry,

- Food, drink & tobacco,

Table 3.23: T-test: Sector's estimates differences with 'All Industry' (1990-2000)

Sector	t-values		Sector	t-values	
	a_1	a_2		a_1	a_2
1	6.5678	2.247	29	-0.4351	-0.6709
2	3.2706	8.9816	30	0.6743	0.5037
3	2.7226	1.604	31	1.8534	1.3276
4	5.6015	1.4372	32	1.4886	1.8532
5	0.3716	3.2941	33	-0.9445	-3.0732
6	8.8905	1.8045	34	-2.0367	1.6197
7	5.3802	-0.6204	35	-1.7980	1.7266
8	4.4938	-1.7075	36	0.7446	-1.4211
9	1.167	1.9828	37	-2.5427	-3.0979
10	1.9056	2.2937	38	0.7648	0.6178
11	0.6499	3.73	39	1.6792	0.674
12	2.8553	33.9781	40	-0.9462	3.9876
13	0.7993	3.2277	41	-2.7175	2.2549
14	-1.8202	2.7719	42	0.8393	2.686
15	3.7854	-0.2603	43	1.2646	-1.2415
16	3.8429	2.1634	44	-1.5813	1.4624
17	0.9208	-0.5703	45	-1.6659	-0.1917
18	2.0512	-0.3620	46	-1.5810	-0.2752
19	0.2623	128.0981	47	-2.6466	2.2411
20	1.7548	-2.0179	48	-0.3081	-2.4235
21	3.1973	-1.1455	49	-1.9559	5.4936
22	0.5578	849.0215	50	-1.5462	-0.5319
23	-0.3122	-1.0427	51	-1.3956	-0.8250
24	-1.9406	-2.1336	52	-1.0477	-0.2287
25	-3.1081	-1.6077	53	-3.8181	1.5218
26	0.1594	-0.5397	54	-5.2580	0.5174
27	0.8515	3.7547	55	-3.2827	1.5202
28	1.7232	-3.6380	56	-0.3326	-4.2161

- Pulp, paper & paper products,
- Printing & publishing,
- Mineral oil refining, coke & nuclear fuel,
- Chemicals,
- Rubber & plastics,
- Basic metals,
- Office machinery,

- Electronic valves and tubes,
- Motor vehicles,
- Air transport,
- Supporting and auxiliary transport activities, activities of travel agencies,
- Communications,
- Renting of machinery and equipment,
- Research and development.

The level of the increasing returns in these sectors is therefore higher than the average one. No clear pattern emerges, as these sectors are part of the primary as well as manufacturing or service sectors.

For 7 of the 56 sectors, the estimated Verdoorn coefficient is significantly lower than the aggregate one for the period 1990-2000. Among these, the following corresponds to sectors where the coefficient appeared non significantly different from zero:

- Radio and television receiver,
- Hotels and catering,
- Computer and related activities.
- Real estate activities.

The remaining three sectors, show increasing returns (a_2 significantly different from zero and b_2 significnatly different from one), but these are significantly lower than the average. The estimated value of the Verdoorn coefficient is significantly lower than the estimated value of these coefficient over all industries:

- Insulated wire,
- Building and repairing of ships and boats,
- Construction.

Table 3.24: T-test: Differences among periods (1990-2000 vs. 1980-1990)

Sector	t-values		Sector	t-values	
	a_1	a_2		a_1	a_2
1	-0.9017	2.3471	29	-0.9010	-0.4089
2	0.9312	-2.3535	30	-1.1473	2.6652
3	2.3365	0.3698	31	-1.6404	3.1559
4	1.2687	-0.8643	32	2.0465	0.5965
5	-1.0064	0.8763	33	-3.7321	1.0563
6	0.1245	-11.4991	34	-1.6136	2.2444
7	1.7604	-0.8454	35	1.1017	-1.8681
8	0.1531	0.2879	36	1.0397	-1.7569
9	-1.0688	-8.1185	37	2.7702	-4.5098
10	0.1857	-0.3868	38	0.5134	-0.4421
11	2.6563	-3.6507	39	-0.2142	-1.3632
12	1.3608	19.4555	40	-1.3439	4.2758
13	0.479	-1.3337	41	-2.3202	1.7034
14	-1.3507	0.4601	42	1.3931	-0.8560
15	-2.4133	-0.8316	43	6.1585	-4.9543
16	-1.2889	0.3786	44	1.6783	-1.0702
17	-1.2550	-0.5686	45	2.3254	-4.5992
18	-0.4224	-1.8785	46	1.1658	-0.7290
19	-0.4737	6.1903	47	1.0447	-1.9195
20	-0.2286	-2.5285	48	0.8121	-2.3746
21	0.6603	-1.0296	49	-0.1686	8.3915
22	-2.3394	115.5208	50	1.0952	-1.3085
23	-2.7326	-6.3184	51	-0.5479	0.1927
24	-3.5640	-2.9159	52	2.8211	-1.0692
25	-3.5813	-1.8470	53	0.0698	1.0989
26	-0.1110	-1.2228	54	4.6833	-5.1243
27	-0.7933	4.6427	55	0.3975	-0.0423
28	-1.1352	-2.3929	56	0.8767	-0.3832

To stress the changes from period to period, we then compare the estimated values of the Verdoorn coefficient for each sectors as estimated for the period 1990-2000 to the estimated value for the period 1980-1990. The results of this test are detailed in Table 3.24. For a large number of sectors (32 out of 56) the estimated values for the Verdoorn coefficient for the 90s is not significantly different from the estimated value for the 80s.

For 10 sectors the measure of the level of increasing returns through the Verdoorn coefficient is significantly higher for 1990-2000 then for 1980-1990:

- Agriculture,

- Mineral oil refining, coke & nuclear fuel,

- Office machinery,
- Electronic valves and tubes,
- Motor vehicles,
- Railroad equipment and transport equipment,
- Furniture, miscellaneous manufacturing; recycling,
- Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel,
- Air transport,
- Research and development.

For the remaining 14 sectors the estimated values of the Verdoorn coefficient are significantly lower for 1990-2000 than for 1980-1990. Among these, for the following four sectors this difference is explained by the fact that for the last period, the estimated value for the coefficient is not significantly different from zero any more while it was for 1980-1990:

- Radio and television receivers,
- Building and repairing of ships and boats,
- Hotels & catering,
- Computer and related activities.

For the other 10, the estimated coefficient is significantly different from zero for the two periods but significantly lower in the 90s then the 80s:

- Forestry,
- Textiles,
- Wood & products of wood and cork,
- Printing & publishing ,
- Insulated wire,
- Telecommunication equipment,
- Financial intermediation, except insurance and pension funding,

- Activities auxiliary to financial intermediation,
- Renting of machinery and equipment,
- Health and social work.

For all these sectors, the level of increasing returns decreased but remained positive.

The estimation of the Verdoorn coefficient at the aggregate level appeared significantly lower for 1990-2000 than for 1980-1990. However this decrease might not necessarily be due to a general reduction of the increasing returns among sectors. Only 14 sectors over 56 are characterised by increasing returns significantly lower for the 90s then for the 80s. In other words the decrease of the aggregate level estimates might be explained by a change in the sectoral structure of the economies.

The results of the sectoral estimations of the Kaldor-Verdoorn Law for the period 1990-2000 can be summarised as follows:

Result 5 *The estimations show that the Kaldor-Verdoorn Law still holds for the period 1990-2000, at the aggregate, as well as the sectoral levels. However, the aggregated estimated value of the Verdoorn coefficient has significantly decreased. The number of sectors where the Law does not hold has increased and concern every sector of activity (primary, manufacturing as well as services). If the aggregate value of the coefficient has significantly decreased from the 80s to the 90s, only a minority of sectors show the same trend (14 over 56).*

If the Kaldor-Verdoorn Law holds at the aggregate level as well as for most of the sectors, the estimates for the period 1990-2000 reveal a higher degree of heterogeneity then for the period 1980-1990. A larger number of sectors do not exhibit significant increasing returns. Moreover, a larger number of sectors' estimations are significantly different from the aggregated estimations. Simultaneously, the estimates show a higher degree of robustness for the 90s than it exhibited in the 80s. Hence, these observations lead to the conclusion that the level of increasing returns tends to become more dispersed during the 90s but more robust.

The decrease in the estimated value of the Verdoorn coefficient for the aggregated level, does not correspond to a general trend at the sectoral level. Hence most of the sectors do not exhibit significant changes in the value of this coefficient. In this sense, the aggregated changes seems only due to few sectors. The aggregate result might be explained by the relative importance of a small number of sectors. In other words both the macro and meso structure and their changes matter to understand productivity dynamics at an aggregated level.

3.3 Conclusion: Towards a 'Kaldor-Verdoorn' Paradox ?

We aim in this chapter to answer the following question: Does the Kaldor-Verdoorn Law still mean something ? Kaldor (1966) referring to Verdoorn (1949) stressed the existence of increasing returns at the macro-economic level estimating first a linear relationship between the growth rate of labour productivity and the GDP growth rate and second a linear relationship between the growth rate of employment and the growth rate of GDP. These estimates turned out to be significant and robust. For Kaldor (1966) this evidence showed that capitalists economies were exhibiting increasing returns. These increasing returns constitute one of the key factor for growth, in line with most of the modern growth theories.

These relationships known as the Kaldor-Verdoorn Law constitute a simple formal measure for investigating the existence of increasing returns. However, the reliability of the Law has been put into question, first due to its strong sensitiveness to the choice of the sample, as stressed by Rowthorn (1975). Second, from the 1980s on, Boyer and Petit (1981,1991) among others, questioned the persistence of the law. However they imputed this evidence to the structural change that occurred in the most advanced economies since 1970, contrary to Rowthorn (1975) who focused on technical reasons. For these authors, the shift towards service activities, the crisis in manufacturing activities, as well as changes in demand regimes and the increasing of the R&D based technical change replacing the capital embodied technical change questioned the persistence of the Law. Kaldor (1966, 1972, 1981) himself claimed that increasing returns are the characteristic of large scale manufacturing activities.

We first estimate the law at the aggregate level for various periods in time, using different samples of countries. The results of these estimations show the following. First when the sample is restricted to the sample of countries used by Kaldor (1966), the law does not hold any more after 1970. This result can be seen as in continuity with the results found by Boyer and Petit (1981) for the 1970s. This might therefore support the argument put forward by Boyer and Petit, that the changes in both production and demand structures led to the disappearing of increasing returns as described by the Kaldor-Verdoorn Law. However when we extend the sample to the entire pre-1974 OECD member countries, the results drastically modifies. The law is verified after 1980. Two possible explanations can be found to this result. The first, technical, is the argument put forward by Rowthorn (1975), there could be outliers that biases the results. The second is linked to the division of labour and structural change occurring in the most advanced economies and which have affected the peripheral ones. These structural changes are combined with changes in the specialisation patterns. Increasing returns being dependent on the structure of the economies, we can infer that these changes explain that the sources of increasing returns are from 1970 onwards rather found in the peripheral countries. The understanding of aggregate productivity dynamics is therefore highly linked to the understanding of the macro-frame and its changes.

We then estimate the Kaldor-Verdoorn Law at the sectoral level for the two last decades. These estimations show that for the two periods and the majority of sectors, including the non-manufacturing sectors, the law holds significantly. The empirical results, moreover, show a tendency towards a higher heterogeneity in the levels and significance of the estimated parameters of the law for the last period. This heterogeneity is however not linked to the traditional distinction between manufacturing and non-manufacturing sectors as considered by Kaldor (1966). This might put into question the arguments put forward by Boyer and Petit (1981, 1991).

The estimations also put forward another change occurring between the two periods: The estimated values of the parameters of the law, and therefore the level of increasing returns, decreased significantly. This decrease is not linked to a general trend in the estimates at the sectoral level but rather linked to changes in a limited number of sectors. This again stresses the importance of the macro-frame and its changes in understanding the aggregated productivity dynamics.

The results of these two sets of estimations might be somehow paradoxical. The arguments put forward in explaining the different results occurring at the macro-level, based on Boyer and Petit (1981, 1991), relied on structural change and de-industrialisation of the most advanced economies and the migration of these activities towards peripheral economies. However, sectoral estimates showed that not only manufacturing activities exhibit increasing returns during the 80s and the 90s, but most of the considered sectors. De-industrialisation does not then seem to provide a clear explanation for these empirical facts. The tendency towards more heterogeneous values of the increasing returns shows that the differences among sector's endowments in increasing returns do not rely anymore on the traditional distinction between primary, secondary and tertiary activity, as stressed by Kaldor (1966), but on a more subtle distinction. This requires future investigations, particularly on the micro-determinants of these increasing returns.

Chapter 4

Evolutionary Modelling Technological Dynamics And The Kaldor-Verdoorn Law

As illustrated by the previous chapters, the Kaldor-Verdoorn Law proposes a simple alternative for the empirical identification of the existence of increasing returns at the aggregated level. The use of the Kaldor-Verdoornn Law, because of its aggregated form, allows to avoid the "abuse" of micro-level assumptions, either on the functional form of an aggregate production function, or on the behaviours of economic agents. The empirical validation of the law, as shown in the previous chapters is limited to the identification and quantification of the increasing returns.

The Kaldor-Verdoorn Law itself does not provide any explanation on the mechanisms underlying technical change seems. According to Kaldor (1966), however, the increasing returns are of a twofold type: Static increasing returns corresponds to the traditional increasing returns to scale usually attributed to labour specialisation and/or learning-by-doing. Dynamic increasing returns are attributed to gains in efficiency due to the replacement of the production capacities through investments. These foundations brought to the Kaldor-Verdoorn Law by Kaldor remained verbal. The Schumpeterian/Evolutionary approach could, as discussed in Chapter 2, potentially provide a formal micro-foundation to the Kaldor-Verdoorn Law. They root the existence of increasing returns in the micro-dynamics resulting from the emergence and diffusion of technologies.

We develop, in this chapter, a simple micro-founded model of technical change in-line with the evolutionary literature. We use the model to test, first, the presence of a Kaldor-Verdoorn Law as a property of the micro dynamics. Second, we bring into light the effect of some key micro-characteristics of the model on the estimates of the Kaldor-Verdoorn Law.

The chapter is organised as follows: Next section describes the micro-founded model, and the following one provides the results from numerical simulations.

4.1 An Evolutionary model of technical change and firm dynamics

As discussed in Chapter 2, the evolutionary analysis of technical change proposes a formal representation of Schumpeter's thought. Technical change, as a key factor for economic dynamics, emerges unevenly and unpredictably. It then diffuses across the economies, disrupting the established economic equilibrium. Technical change is therefore an out-of-equilibrium process.

The evolutionary interpretation of Schumpeter's analysis relies on analogies with the formalisation to be found in evolutionary biology. An economic system is assumed to be composed by one (or more) population of agents. These latter are defined by a set of characteristics, subject to mutations. These mutations emerge unevenly and unpredictably among the agents, generating and sustaining heterogeneity in the population's characteristics. The agents composing the population(s) are subject to selection mechanisms. The selection mechanism defines the level of performance of the economic agents as function of agents characteristics.

Following the traditional evolutionary modelling[1] the model, we propose here, relies on a population of firms. These firms play two distinct but complementary roles in our model. They first generate technological shocks in the system, developing and using new technologies. We choose here to distinguish two phases of this process :

- Exploration or R&D. Firms first search for new production facilities, through innovation or adaptation of existing production facilities. The outcome of the R&D process is uncertain, and defines efficiency (in terms of productivity) of the new generation of capital goods.

- Exploitation of R&D outcome. This second stage requires that firms invest to incorporate the outcome of research in the production process. This second stage is funded by profits, and then directly dependent on the success of previous investments.

[1]See Kwasnicki (2001) for a comprehensive survey of evolutionary models of industrial dynamics, Silverberg and Verspagen (1995) for a comprehensive survey of evolutionary growth models.

The first phase aims to tackle the uneven and unpredictable nature of technological shocks. The second phase, being dependent on past performances determines the cumulative or path dependant nature of technical change.

The second role played by firms is to favour the diffusion of technologies into the economic system. The selection mechanisms sorts out the best performing firms, which act as a channel for the diffusion of the most efficient technologies. The firms as considered in the model are assumed to be bounded rational. They are not conscious of the selection mechanisms, and therefore do not directly try to respond to it. Firms apply simple decision rule in terms of investment decision, pricing rule or technology adoption. The aggregate dynamics emerging from the model are then simply due to the combination of mutation and selection dynamics into an heterogeneous and bounded rational population.

This section is organised as follows: We first characterise the agents composing our population, then describe the selection mechanisms, and finish with the presentation of the mutation processes.

4.1.1 Firms characteristics: Defining the population.

Our model is structured around a population of firms indexed i, with $i \in [1; I]$. In the short run (i.e. at each time step t), a given firms i is represented by a production function characterised by constant returns to scale. Firms' production process uses labour as a unique production factor. Capital enters indirectly in the production function. The level of labour productivity depends on the accumulated generations of capital goods. Investment in the different generations of capital goods will increase labour productivity. The production function will then be represented as follows :

$$Y_{i,t} = A_{i,t-1} L_{i,t} \tag{4.1}$$

where $Y_{i,t}$ is the output of firm i at time t. $A_{i,t-1}$ represents labour productivity and $L_{i,t}$ the labour force employed in the production process. The output is constrained by the demand for the firms' products. The level of aggregate demand (D_t) is set exogeneously. Aggregate demand is then allocated to each firms according to the selection process setting firms' market shares ($z_{i,t}$). The level of production of each firm is computed as a follows:

$$Y_{i,t} = z_{i,t} D_t$$

Labour productivity is deduced from the accumulation through time of capital goods. Each vintage of capital good embodies a level of labour productivity. Hence at every time step labour productivity can be expressed by the following equation:

$$A_{i,t} = \frac{I_{i,t} a_{i,t-1}}{\sum_{\tau=1}^{t} I_{i,\tau}} + \frac{\sum_{\tau=1}^{t-1} I_{i,j,\tau}}{\sum_{\tau=1}^{t} I_{i,\tau}} A_{i,t-1} \tag{4.2}$$

where $a_{i,t-1}$ represents the labour productivity embodied in the capital good developed by i during period $t-1$. $I_{i,t}$ represents the level of investment in capital goods of the firm.

Firms set prices through a mark-up process. This mark-up is applied to the production costs (i.e. labour cost). To simplify the model, the costs linked to R&D activity are financed by profits. Thus prices can be represented as follows:

$$p_{i,t} = (1+\mu)\frac{w}{A_{i,t-1}} \tag{4.3}$$

where $p_{i,t}$ represents the price set by firm i at time t, μ the mark-up coefficient and w the nominal wage set exogeneously. It should be noted that we assume here that the mark-up coefficients are fixed for each firms in a given economy.

The firm's profit level will then be computed as follows:

$$\Pi_{i,t} = p_{i,t} Y_{i,t} - w L_{i,t} = (1+\mu)\frac{w}{A_{i,t-1}} Y_{i,t} - w\frac{Y_{i,t}}{A_{i,t-1}}$$

$$\Pi_{i,t} = \mu\frac{w}{A_{i,t-1}} Y_{i,t} \tag{4.4}$$

In the model profits constitutes the only financial resource for firms' investments. In other words, all the decisions taken by the firms are constrained by their profits. Their ability to capture demand shares, due to their past performances therefore directly affect all their decision potential.

4.1.2 Defining firms performance: The selection mechanisms.

The selection mechanism represents, in an evolutionary system, the core of its dynamics. It sorts the various components of a population, creating motion in the system, and allocating resources within the population. The selection process is usually considered by Evolutionary economics as a metaphor for the competition mechanisms. We choose here to use a replicator dynamics to model the selection mechanisms [2]. The replicator dynamics is usually considered as a formal representation of Fisher's principle of natural selection.

[2] A comprehensive view on selection mechanisms and the replicator dynamics in evolutionary economics can be found in Metcalfe (1998)

This principle can be summarised as follows: The share of groups of individuals in a population is favoured by their relative fitness level with respect to the average. This average level depends itself on the shares of every groups, such that the selection mechanisms tend to favour the fittest components of a population. Formally the replicator equation defines the increase (decrease) in the share of a group of individuals as a function of the distance between the fitness level of the group and the average fitness level. The higher the distance, the higher the growth of the share.

We use this mechanism to model the competition among firms. The replicator dynamics defines firms' market shares. These market shares are function of firms relative competitiveness. The latter is measured as the distance between the firms competitiveness level ($E_{i,t}$) and the average competitiveness level ($\bar{E}_t$), normalised by the average. The market share of each firm are computed as follows :

$$z_{i,t} = z_{i,t-1} \left(1 + \phi \left(\frac{E_{i,t} - \bar{E}_t}{\bar{E}_t} \right) \right) \tag{4.5}$$

where $z_{i,t}$ represents the market share of firm i, $p_{i,t}$ the price of its product, $E_{i,c,t}$ stands for firm i's level of competitiveness:

$$E_{i,c,t} = \frac{1}{p_{i,c,t}}$$

$\bar{E}_t$ the average competitiveness on the international market, given by:

$$\bar{E}_t = \sum_{c,i} z_{i,c,t-1} E_{i,c,t}$$

The parameter ϕ measures sensitivity to changes in competitiveness. The closer ϕ tends to 0 the more rigid the selection with respect to price competitiveness.

Finally, firms exit the market if their market share is lower then $\bar{z}$. These are replaced by firms characterised by the average values of the technological variables within the economy of these exiting firms and a market share equal to $\bar{z}$. In this respect the number of firms remains constant. An innovator that exits is replaced by an innovator, and an imitator by an another imitator. The proportion of innovators (imitators) therefore remains constant.[3]

[3]This proportion is set to 50% for the simulations

4.1.3 Changes in Firms characteristics: The mutation mechanisms

The last key feature of an evolutionary model concerns the mutation aspects. Mutation mechanisms insure that the system remains in motion. As seen previously, the dynamics of the system is linked to selection mechanisms. The persistence of selection dynamics requires some degrees of heterogeneity among the characteristics of the agents. But through time, selection limits the level of heterogeneity in the system. The mutation of agents characteristics then generates and sustain some heterogeneity among the agents.

The mutation process affects the production processes of the firms through labour productivity. The process of technical improvement can be divided into two distinct phases. Firms explore new technological possibilities, through local search (innovation) or by capturing external technological possibilities (imitation). This process leads to a production design that can be exploited by firms in their production process. The second stage consists then in the exploitation of the design by incorporating it as a new capital vintage. The exploitation process is related to investment in capital goods and the exploration is related to investments in research. We assume that a priority is given to investments, and therefore the exploitation of already discovered technologies.

Investment in capital goods is funded by the profits of the firm, using a share ι_i of sales. This Investment is subject to a financial constraint. The latter are completely funded by profits, they cannot exceed the period's profit level. Formally this constraint will be represented as follows:

$$I_{i,t} = min\left\{\iota_i Y_{i,t} \ ; \ \Pi_{i,t}\right\} \tag{4.6}$$

The resources available for investment depend on firms' profits and therefore on the outcome of their previous performances. The model, here, takes into account the sequential nature of the decision process and the existence of a financial constraint linked to the success (or failure) of firms. In this respect the model includes to its evolutionary micro-foundations an additional "Austrian flavour".[4] To simplify the model, we choose to assume a fixed rate of investments per firms ι_i. We thus exclude the possibility for investments to be used as a strategic response to the lack of competitiveness of the firms, as in Llerena and Oltra (2001). This could, however be subject to future developments.

Investments in R&D are a share ρ_i of their sales. R&D investment corre-

[4]See Amendola and Gaffard (1998), p.126.

sponds to the hiring of workers assigned to the research activity :

$$R_{i,t} = \frac{1}{w} \min\{\rho_i Y_{i,t}; \Pi_{i,t} - I_{i,t}\} \tag{4.7}$$

The formalisation of the R&D process is explicitly inspired by evolutionary modelling of technical change. Hence following Nelson and Winter (1982) we will consider that the probability of success of research is an increasing function of R&D investments. The R&D process, followed by each firms, is represented by the algorithm that follows:

1. Firms draw a number from a uniform distribution on [0 ; 1]. If this number is contained in the interval $\left[0 \; ; \; \frac{R_{i,t}}{Y_{i,t}}\right]$, the R&D is successful. The probability of success of the R&D process therefore grows with the number of workers hired for the research activity. In other words it grows when increasing the R&D investments.

2. If R&D is successful, its outcome is defined through the following stochastic process. We differentiate here explicitly innovative firms from imitative ones:

$$a_{i,t} = \max\{a_{i,t-1} + \epsilon_{i,t}; a_{i,t}\} \tag{4.8}$$

$$\epsilon_{i,c,t} \sim N(0; \sigma_{i,t}) \tag{4.9}$$

$$\text{with} \begin{cases} \sigma_{i,t} = \sigma & \text{if the firm is an innovator} \\ \sigma_{i,t} = \chi(\bar{a}_t - a_{i,t}) & \text{if the firm is an imitator} \end{cases} \tag{4.10}$$

The outcome of the R&D process defines the labour productivity embodied in the newly discovered capital vintage ($a_{i,t}$). $\bar{a}_t$ represents the average productivity level embodied in the latest capital vintages developed by firms. It is formally computed as:

$$\bar{a}_t = \sum_i z_{i,t} a_{i,t-1}$$

In the case of innovators, the outcome of R&D corresponds to a 'local search' , à la Nelson and Winter (1982), as the stochastic process is centred on the previous level of productivity. For imitators, the outcome of the R&D process correspond to a randomly defined reduction of their productivity gap.

4.2 Evolutionary micro-founded technical change and the Kaldor-Verdoorn Law: Main Simulation Results

As stated in the introduction to this chapter, we aim to show that, under some conditions, a Kaldor-Verdoorn Law can emerge from the productivity dynamics generated by a simple evolutionary model. The model as described assumes constant returns to scale in the short-run (i.e. for a given simulation step). In other words we do not assume the existence of static increasing returns at the micro-level. If they appear, these are due to the combination of the two evolutionary dynamics, namely selection and mutation.

To bring this result into light, we first identify the effect of the micro-dynamics of the model on the aggregate productivity dynamics. We can decompose the micro-dynamics into three main phases:

1. The emergence of technological shocks. This phase corresponds to the arrival of new capital vintages. It occurs at the level of the innovative firms as an outcome the R&D process.

2. The adoption of the technological shocks. This phase corresponds to the introduction of the new capital vintages in the production process.

3. The diffusion of the shocks among the population. The diffusion phase occurs through two channels. First through the adoption by the imitating firms. Second through the selection process that allocates more resources to the fittest firms. These have benefited from technological shocks and exploited them.

These phases of the micro-dynamics are directly affected by a set of parameters. We then focus the analysis on the set of parameters described bellow:

- ι_i, is defined above as the share of ressources devoted to investments in capital goods. We assume through the entire simulation procedure that ρ, the share of ressources devoted to R&D equals $(1 - \iota_i)$. The parameter ι_i, therefore also set the allocation of ressources between capital and research investments. As ι_i decreases, more resources are devoted to R&D. This favours the emergence of technological shocks. On the other side, as ι_i increases, more resources are devoted to capital investments. This favours the adoption of the technological shocks, translating the outcome of the shocks into productivity gains.

- σ, corresponds to the standard deviation of the stochastic process defining the outcome of the R&D process for the innovator. The parameter, therefore, controls the amplitude of the technological shocks, when arising. Increasing σ, increases the potential jumps in productivity due to technical shocks.

- *The exogeneous growth rate of aggregate demand* directly affects the aggregate level of the ressources to be allocated among firms. Increasing firms ressources favours the adoption of the technological shocks *via* the investments in capital goods.

- χ measures the appropriability of technological spillovers. This parameters controls the diffusion of technological shocks to the imitative firms, and their ability to reduce their productivity gaps.

- ϕ defines the sensitiveness of the replicator dynamics. If this parameter do not affect directly technical change, it fosters the selection mechanisms. This affects the diffusion of technological shocks among firms. It first favours the better performing firms in allocating ressources to the latter. Second, it favours the diffusion of technological shocks through imitation.

4.2.1 presents the results of these investigations. 4.2.2 presents the results of the estimation of the Kaldor-Verdoorn Law on the data generated by the numerical simulations. The analysis focuses on the effect of the three phases described previously on the value of the Verdoorn coefficient, that measures the degree of increasing returns, it level of significance, and its explanatory power.

The numerical simulation are conducted as follows: Our population of firms counts 20 elements. 10 firms are set as innovators, 10 as imitators. Every simulation run lasts 500 periods, this allows the dynamics generated to reach stable states. We replicate every simulation configurations 20 times. The results presented below represent the average outcome over the 20 replications. Every firm composing the model are set identically at the initial step. Heterogeneity is not assumed initially but emerges from the dynamics. The details of the parameter setting are presented in Table 4.2.

4.2.1 Micro-characteristics and aggregate productivity dynamics

We first present the simulation results emerging with the changes in the various parameters controling for the three phases of technological change on productivity dynamics. The latter is measured using 4 different indicators. First, we measure the productivity level at the end of the simulations. It captures the overall effect of the various parameters on productivity. The other three indicators are respectively the productivity growth rates over the 50, 100 and 250 first simulation steps. We choose to measure the productivity growth rates over various time periods to capture some possible transitory effects.

The first set of simulations concern the phase of emergence of the technological shocks. We therefore focus on the effects of the parameters ι and $sigma$ on the dynamics. Figures 4.1, 4.2, 4.3 and 4.4 present the effect of variations in ι and σ on productivity dynamics. The four figures show some coherent and predictable results. As shown by Figure 4.1, increasing ι decreases the aggregate productivity level, while increasing σ increases this level.

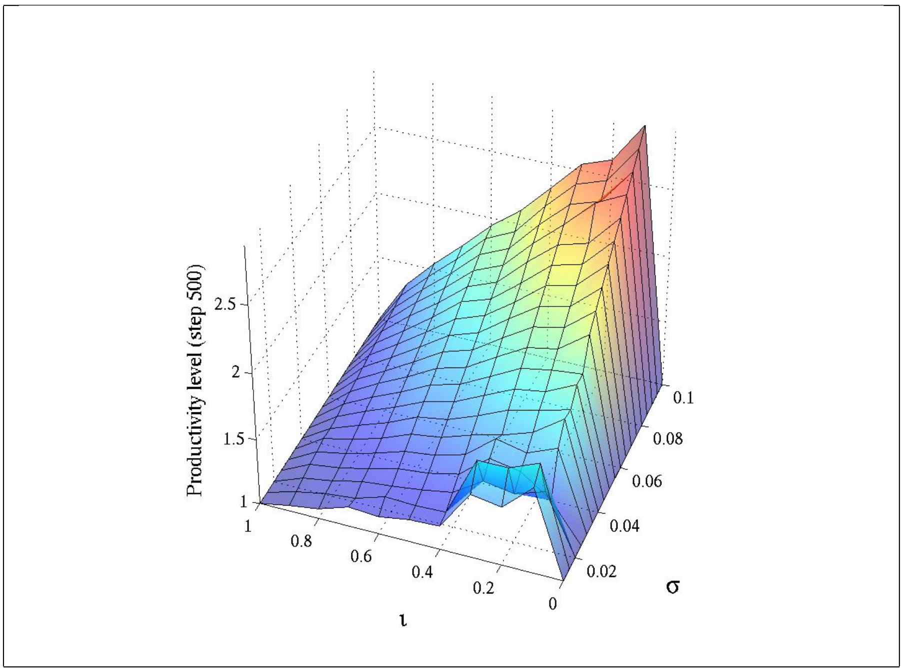

Figure 4.1: Productivity level after 500 steps, ι vs. σ

Figure 4.2 presents similar results. On the one hand, increasing ι decreases the productivity growth rate. On the other hand increasing σ increases the productivity growth rate. This result found for the 50 first step growth rate is similar over 100 and 250 steps as shown by Figure 4.3 and 4.4.

The parameter ι controls the share of resources devoted by the firms

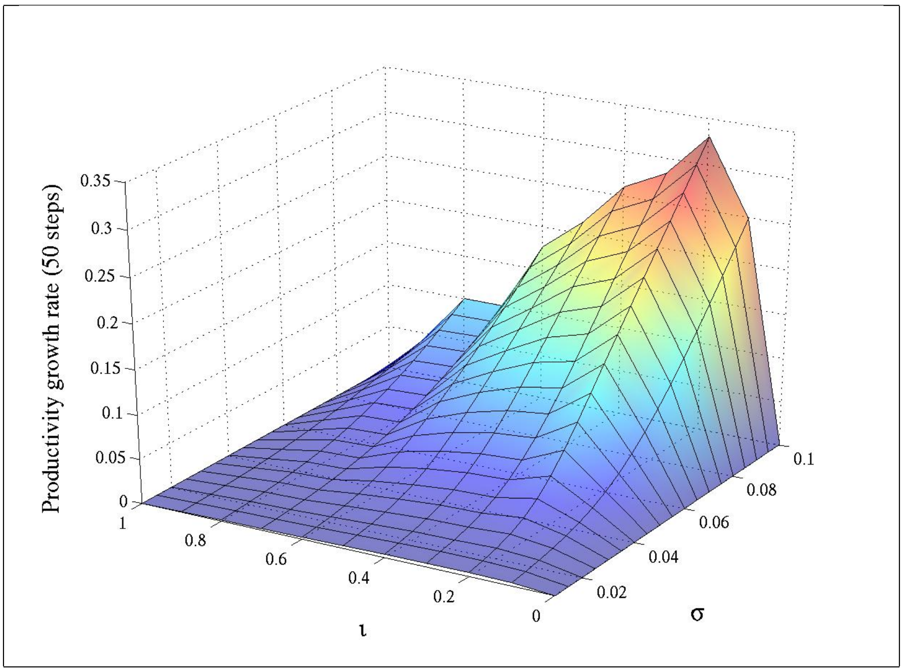

Figure 4.2: Productivity growth rate (50 first steps), ι vs. σ

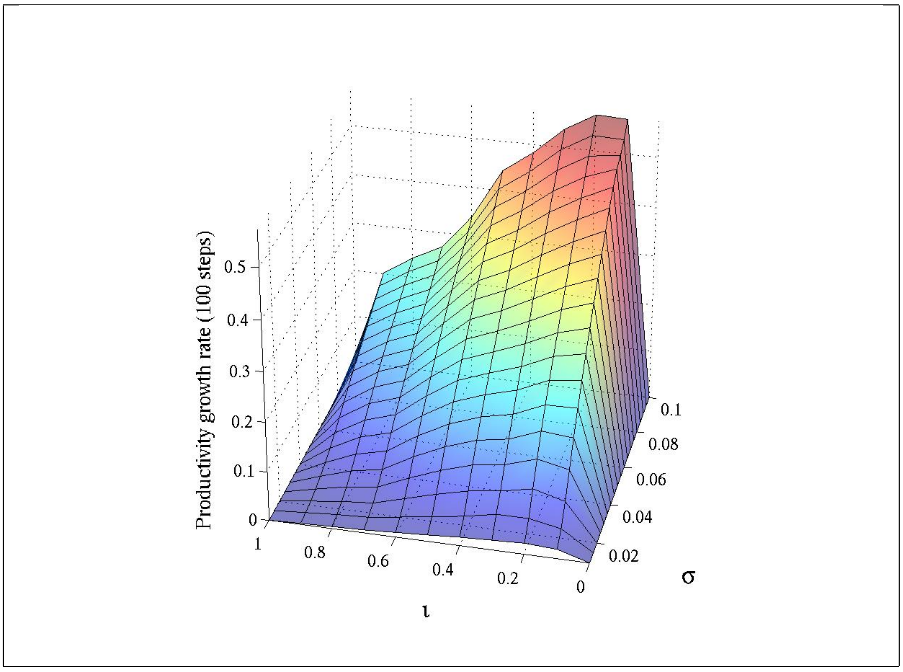

Figure 4.3: Productivity growth rate (100 first steps), ι vs. σ

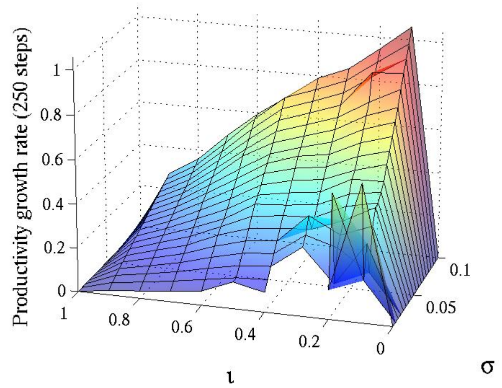

Figure 4.4: Productivity growth rate (250 first steps), ι vs. σ

to their investments in capital goods and by extension, the share of their resources devoted to their investment in R&D. The higher ι, the lower the investments in R&D. Investments in R&D affect directly the probability of success of the R&D process. In other words the higher this investment, the more likely the occurence of a technological shock. Hence, the lower the value of ι the higher the frequency of the technological shocks, as long as ι remains higher than zero. If ι equals zero, then the firms cannot exploit the technological shocks.

The second effect that comes out concerns the parameter σ. This parameter controls the standard deviation of the stochastic process ruling the outcome of the R&D process. Therefore, increasing σ enlarges the amplitude to the technological shock. The potential productivity jumps between two capital vintages is then higher.

These two parameters affect directly the phase of emergence of the technological change. They allow us to control for the frequency and the amplitude of these stochastic shocks.

To sum up, this first set of simulation exhibits the following results: First, the higher the R&D investments, the higher the frequency of the technological shocks and the higher the productivity growth. Second, the higher the amplitude of the technological change induced by these shocks, the higher productivity growth rates.

The second phase concerns the adoption of the technological shocks by the firms. We focus on the effect of changes in ι and in the exogeneous rate of growth of demand. These parameters control respectively for the amount of resources devoted to the exploitation of the R&D outcome, and the amount of resources available for the firms to invest. Figures 4.5, 4.6, 4.7 and 4.8, presents the outcome of various specifications of these two parameters on the aggregate productivity dynamics.

Figure 4.5 presents the effect of these specifications on the aggregate productivity level at the end of the simulation procedure. On the one hand, as found previously, decreasing ι positively affects productivity, as long as ι remains non-null. On the other hand, increasing the exogeneous growth rate of aggregate demand does not seem to affect significantly the productivity levels.

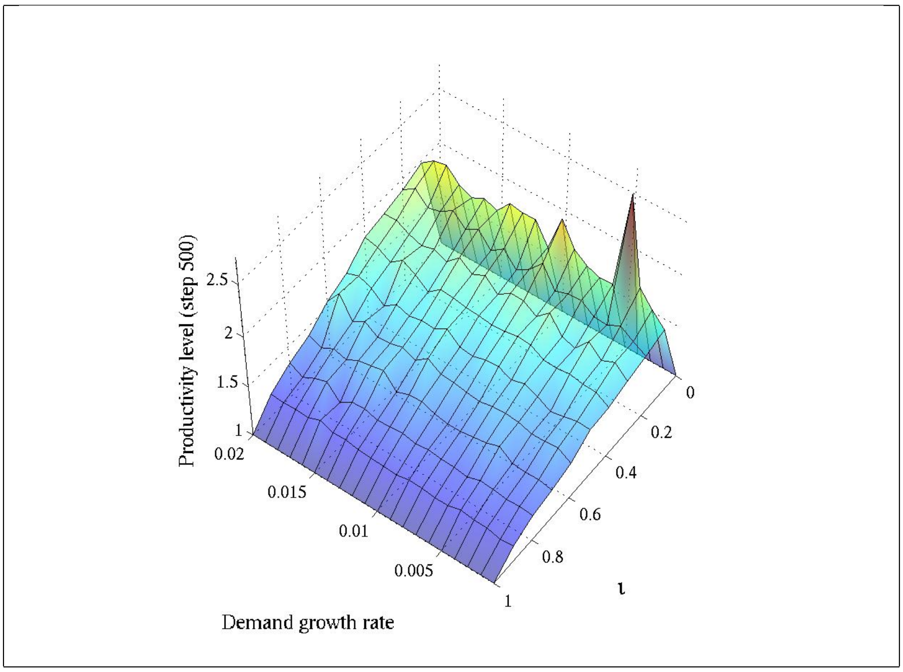

Figure 4.5: Productivity level after 500 steps, ι vs. exogeneous demand growth

Figures 4.6 presents the outcome of the various specifications in terms of productivity growth rates over the 50 first steps. In this case, increasing the resources available to firms, *via* an increase in the exogenous growth rate of demand affects significantly the productivity dynamics. Moreover, Figure 4.6 clearly shows that this effect is more important for low values of ι. Low values of the parameter ι corresponds to the situation in which firms allocates more resources to the phase of emergence of technical change, through investments in R&D, normalised by the level of output. It can be inferred that increasing the aggregate demand, and then the resources of the firms has no impact in this phase. Hence, favouring the adoption of technological shocks through an increase in the resources of the firms can only significantly affect productivity dynamics, when the emergence of these shocks is insured. In this sense, the emergence prevails on the adoption in affecting productivity dynamics.

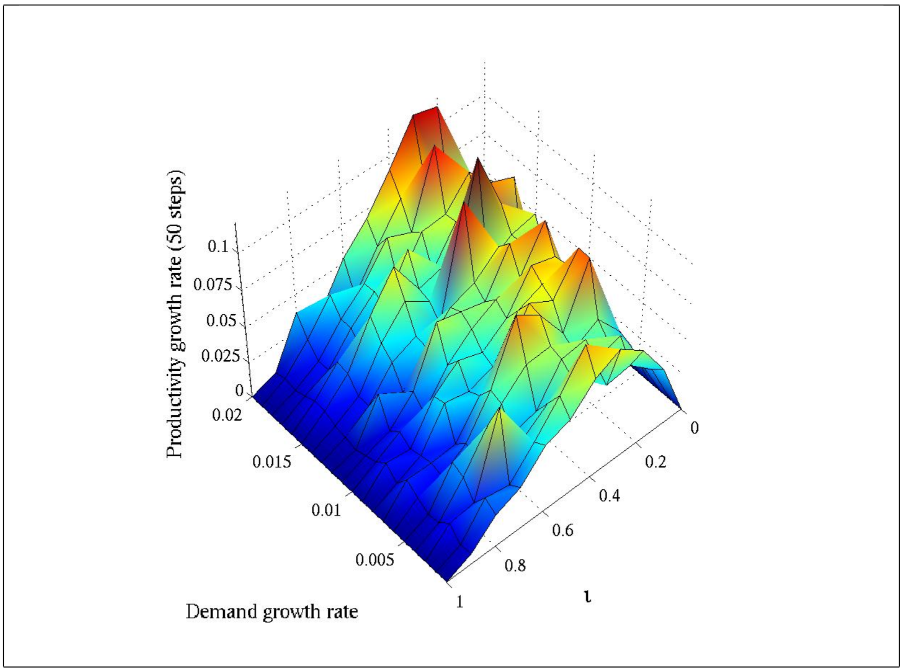

Figure 4.6: Productivity growth rate (50 first steps), ι vs. exogeneous demand growth

This result in terms of productivity growth rates seems to gradually disappear. Figures 4.7 and 4.8 present the result of similar specifications of the parameters on the productivity growth rates over 100 and 250 simulation steps. In these two cases, the effect due to the increase in resources seems less significant. This tend to show that the resource effect in the adoption phase gradually disappear through time.

The effect of the parameters affecting the adoption phase therefore concentrates on the initial periods. This explains why no significant effects are found on the measure of productivity level at the final period of the simulations. This phenomenon might in turn be due to the evolution of the market structure. Through time the replicator dynamics necessarily leads the system into a monopoly situation. When this situation is reached the aggregate

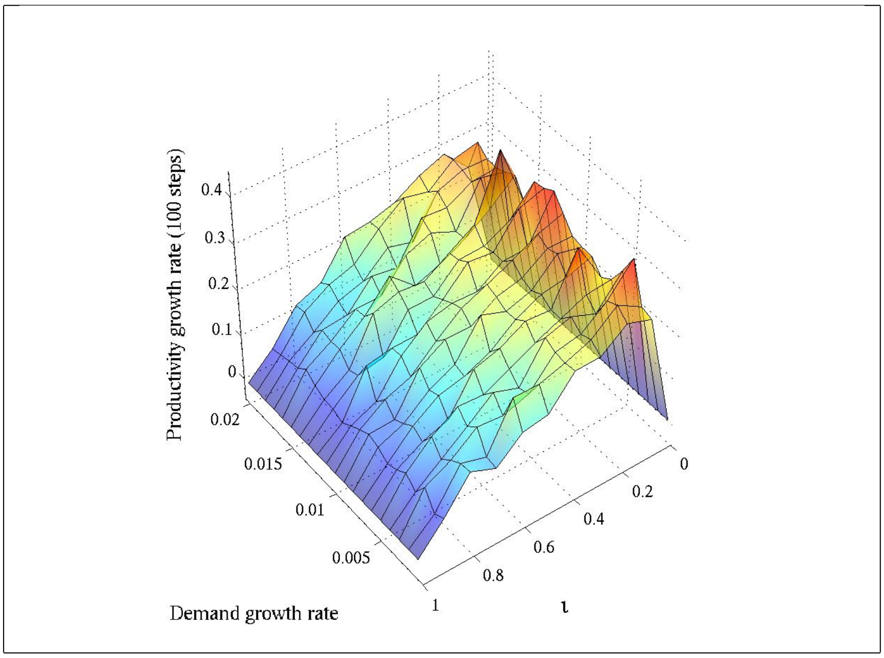

Figure 4.7: Productivity growth rate (100 first steps), ι vs. exogeneous demand growth

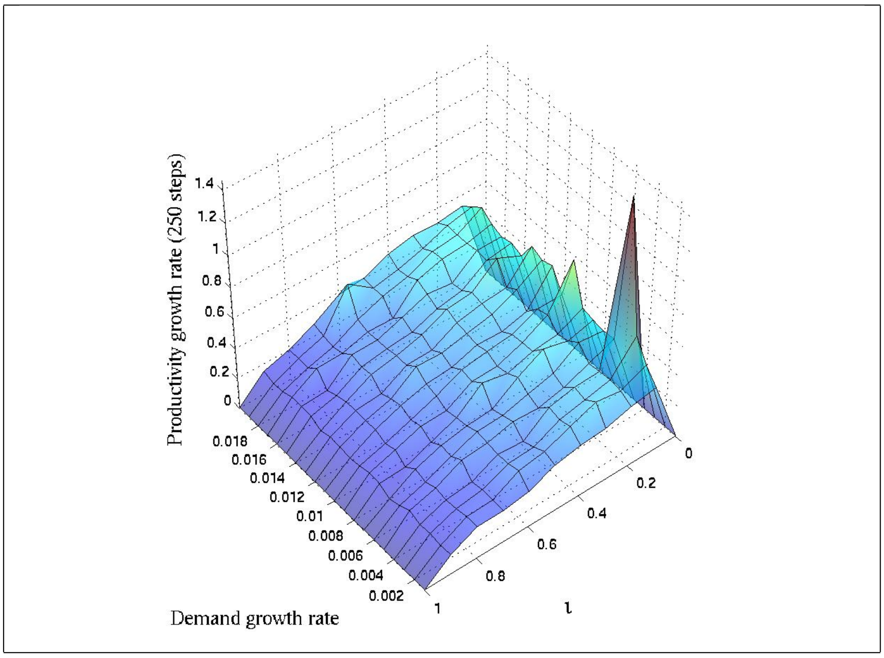

Figure 4.8: Productivity growth rate (250 first steps), ι vs. exogeneous demand growth

dynamics entirely depends on the productivity dynamics of the monopolist firm. Regardless the resources available to this firm, it remains the only firms able to generate technological shocks. This mechanically reduces the frequency of the technological shocks. There is then nothing to adopt.

The last set of simulations concerns the parameters related to the diffusion of technological shocks. We focus here on the effect of changes in χ and ϕ on the productivity dynamics. The parameter χ controls the level of spillover to be absorbed by the imitating firms. The higher χ, the larger the absorption of spillover by the firms, the more these firms reduce their productivity gap. This parameter therefore favours the diffusion of the shocks through imitation. The parameter ϕ controls the sensitiveness of the selection process. It mechanically affects the computation of the aggregated productivity dynamics. The replicator equation defines the market share of the firms. A stronger selection mechanism makes the most competitive firms to faster gain market shares. These firms are those that most benefited from better technological shocks. The higher ϕ, the faster the technological shocks diffuses among the system.

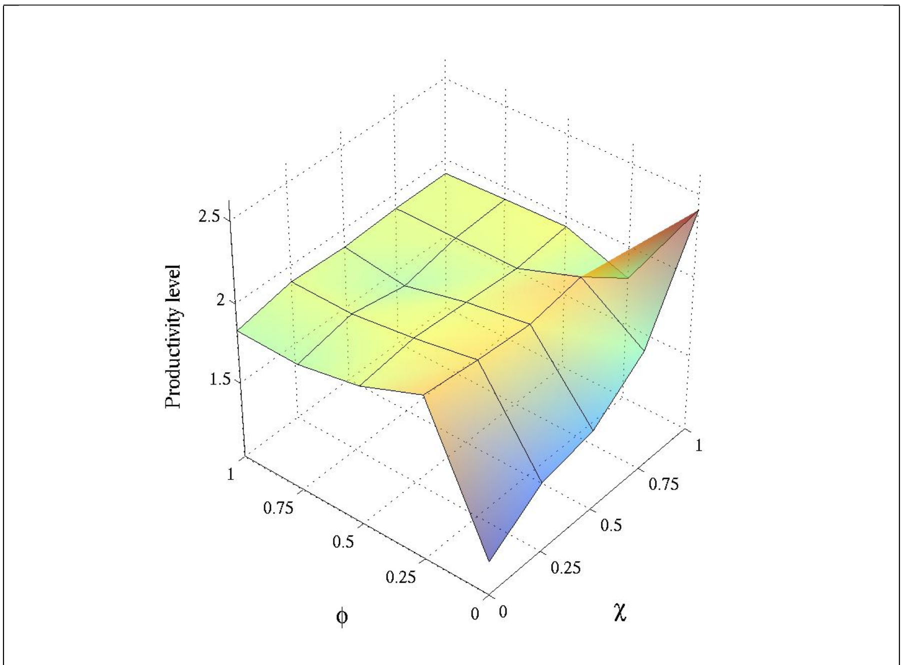

Figure 4.9: Productivity level after 500 steps, ϕ vs. χ

Figure 4.9 presents the outcome in terms of productivity levels of changes in these two parameters. First, this figure clearly shows that, except when the selection mechanisms are neutralised, χ does not seem to affect productivity levels. This results can be explain as follows: Neutralising the selection mechanism allows the firms not to loose market shares and then never exit the market. The ability of firms to generate a technological shock or imitate the existing ones is there independent from their performances. In this case, only the level of spillover available constraint the catching-up of the lagging firms. Second, the effect of the parameter ϕ, according to Figure 4.9, sees limited. It only clearly affect significantly the productivity level, when equal to zero, it neutralises the selection mechanism.

Figure 4.10 presents the outcome of the changes in these parameter on the productivity growth rates over 50 simulation steps. In this case, strengthening the selection mechanism clearly affects the productivity dynamics. This result can be explained by the mechanisms described above. The higher ϕ, the stronger the selection mechanisms and the faster the diffusion of the technological shocks. The parameter χ, slightly affect the dynamics. The effect linked to imitation are largely overtaken by the effects of the selection mechanism. Figure 4.11 presents similar outcomes for the productivity growth rates over 100 steps.

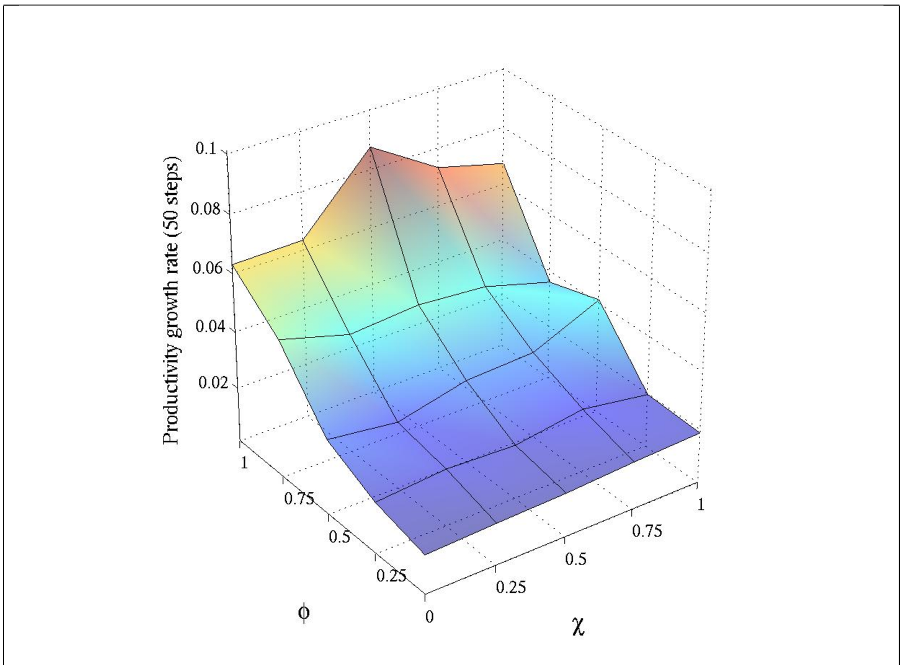

Figure 4.10: Productivity growth rate (50 first steps), ϕ vs. χ

Figure 4.12 presents the productivity growth rates over 250 simulation steps for the various changes of parameters. The clear-cut results previously

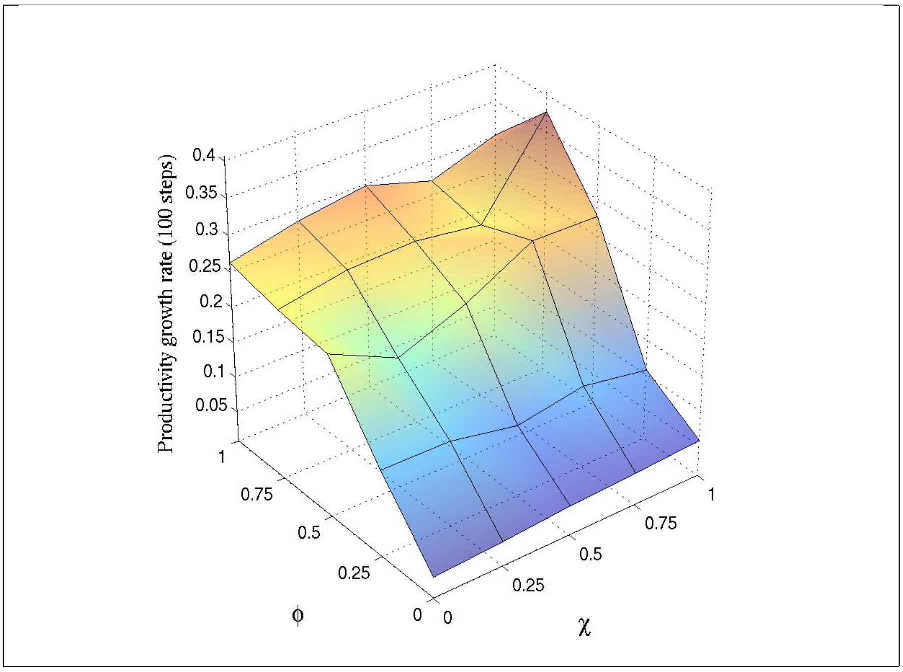

Figure 4.11: Productivity growth rate (100 first steps),ϕ vs. χ

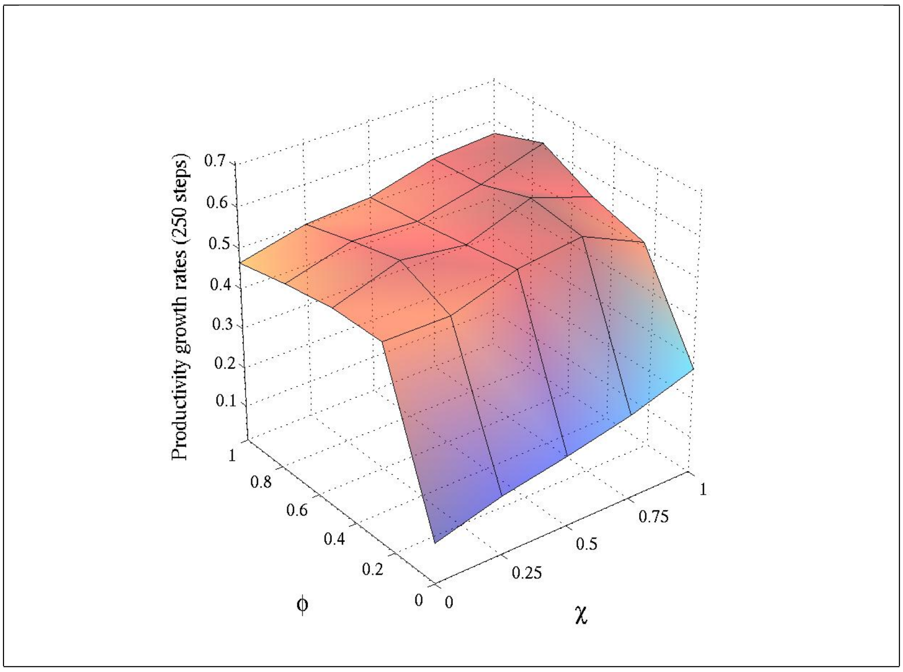

Figure 4.12: Productivity growth rate (250 first steps), ϕ vs. χ

found have disappeared. The only significant difference resides in neutralising or not the selection mechanisms. The result found here is similar to the one found in terms of productivity levels.

The influence of the strength of the selection mechanism is only transitory. This is due to the nature of the selection mechanisms. The replicator dynamics necessarily leads the system to a monopoly (or quasi-monopoly) situation. Once a monopoly situation arises, the aggregate dynamics is only due to the productivity changes of the monopolistic firm. The factors favouring diffusion are then marginal.

This first sub-section has shown some preliminary analysis of the dynamics generated by the model. We can briefly summarise the results found as follows: First, the factors favouring the emergence of technological shocks clearly favours productivity dynamics. Second, the factors favouring the adoption of these shocks if necessary, only transitorily affects the productivity dynamics. Finally, selection mechanisms favour productivity dynamics, favouring the diffusion of the technological shocks. This effect remains transitory.

4.2.2 The Kaldor-Verdoorn Law as an emergent property

The second part of the simualtion analysis aims to show that a Kaldor-Verdoorn Law can emerge from the dynamics generated by a simple evolutionary model. We estimate the Verdoorn specification of the Law as follows:

$$\frac{A_t - A_0}{A_0} = \alpha + \lambda \frac{Y_t - Y_0}{Y_0}$$

A_t is the aggregate level of productivity as generated by the simulations at time t. Y_t measures the aggregate output. This equation is then estimated using the data generated by the simulation model.

The data set is built as follows: The aggregate output is defined by aggregate demand. Aggregate demand grows at an exogenous growth rate. This way we can avoid problems of endogenity of the explaining variable. For every specification of the parameters we replicate the simulations with 20 different values of the exogenous growth rate of demand. We use exactly the same values of this growth rates for all the parameter settings. Hence the vector of the explaining variable are identical among all specifications. The data set for aggregate productivity is generated by the various replications of the simulation for different values of the parameters.

We estimate the Kaldor-Verdoorn Law for various specifications of the parameters previously considered. We then analyse the effect of the changes in the values of these parameters on the estimated value of the Verdoorn coefficient, on the significance level, and on the explainatory power of the estimates. The significance level is measured using Student t, and the explainatory power of the estimates using the corrected R^2.

The first set of estimates focuses on the parameters controlling the emergence of the technological shocks. The results of these estimates are presented in Figures 4.13, 4.14 and 4.15. The estimations are realised using the 50 steps growth rates. One of the main result coming out from these estimates is that the Kaldor-Verdoorn Law holds for various settings of these parameters.

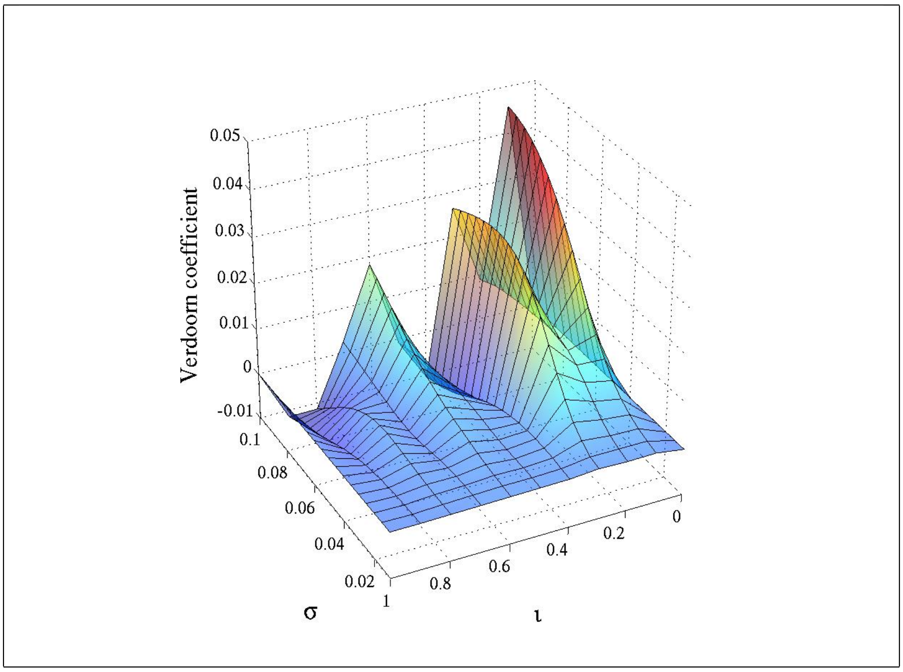

Figure 4.13: Estimated Verdoorn coefficient (50 steps growth rates), ι vs. σ

Figure 4.13 presents the estimated values of the Verdoorn coefficient for different settings of ι and σ. These parameters respectively influence the frequency and the amplitude of technological shocks. As seen in the previous sub-section, these parameters directly affect productivity dynamics. They should therefore positively affect the level of the increasing returns. This is confirmed by the estimated values of the Verdoorn coefficient. First, increasing the value of σ significantly increases the value of the coefficent. Second, increasing the values ι reduces the value of the coefficient. The parameters affecting the emergence of the shock directly affect the level of the increasing returns.

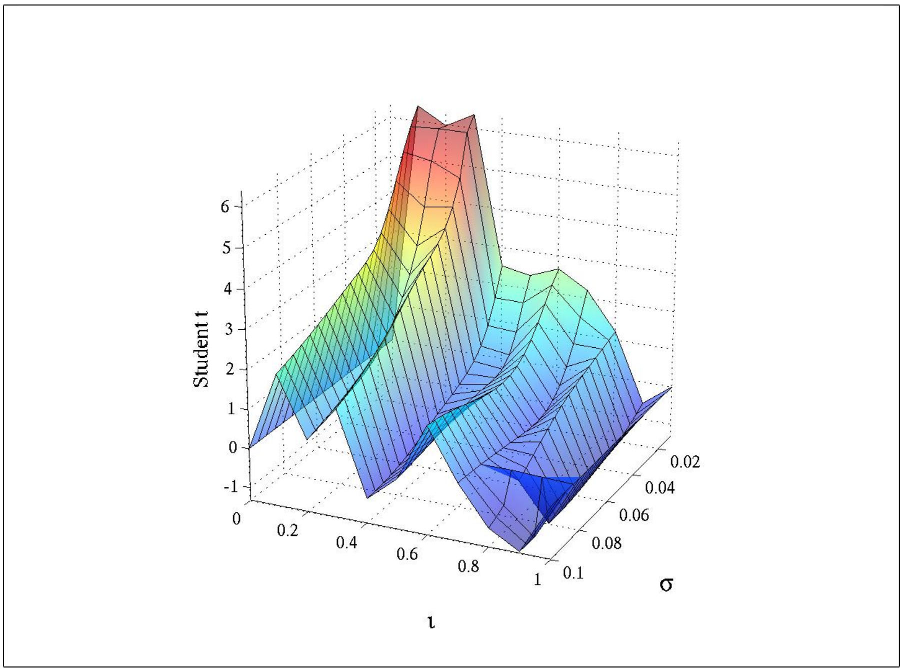

Figure 4.14: Student t for the Verdoorn coefficient (50 steps growth rates), ι vs. σ

Figure 4.14 presents the value of Student t statistics for the estimated coefficients. We focus on this statistic to measure the effect of the changes in the parameters on the significance level of the estimated coefficient. This figure clearly shows a decrease in the Student's t when increasing both ι and σ. This decrease is such that for high values of σ only few of the estimated coefficient are significantly different from zero. Hence, if an increase in the amplitude of the technological shocks increases the value of the Verdoorn coefficient, it tend to be less significant. This tendency is also confirmed by the Figure 4.15, that presents the corrected R^2 of the estimations. Increases in σ also correspond to drastic decreases in this statistic. In other words, increasing the amplitude of technological changes increases the degree of increasing returns but these are less and less significant and show lower explanatory power. This result is due to the stochastic nature of the technological change. Hence, σ corresponds to the standard deviation of the stochastic variable defining the outcome of the R&D process. Increasing σ not only enlarges the potential gains in productivity gaps, these becomes more uneven. These increase in the variability of the technological shocks explains the loss in terms of significance and explanatory power.

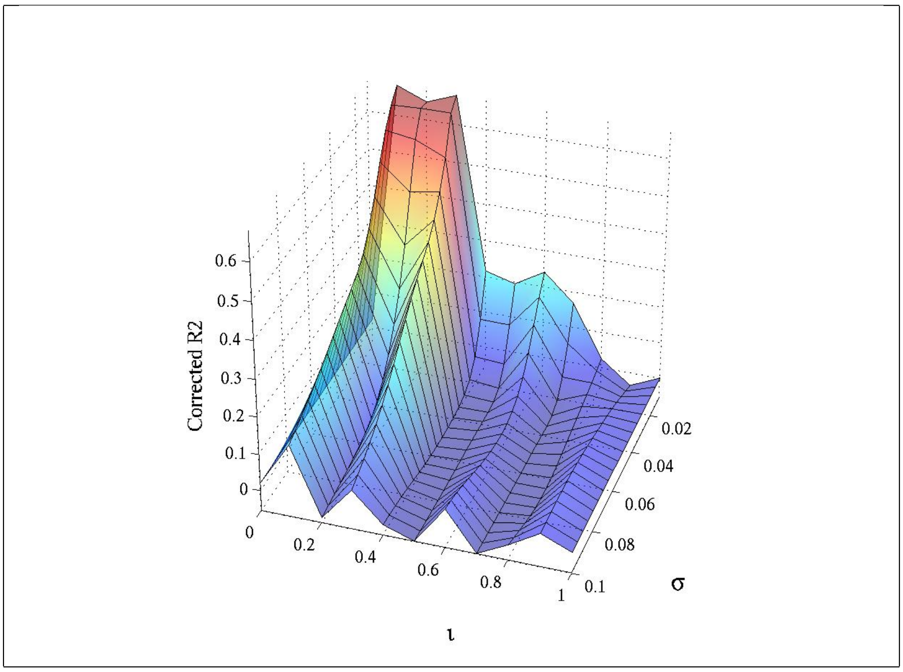

Figure 4.15: Corrected R^2 (50 steps growth rates), ι vs. σ

Result 6 *The higher the amplitude of innovation (σ), the higher the Verdoorn coefficient, therefore, the higher the increasing returns. Simultaneously the estimated coefficient loose their significance and the Law its explanatory power with these increases. The higher the investments in R&D (lower ι), the higher increasing returns. The higher investments in R&D levels preserves the significance of the Law for high values of σ.*

The second set of estimations concerns the parameters affecting the diffusion of the technological shocks on the system. We focus the analysis on the effect of changes in the strength of the selection mechanisms (ϕ) and the absorptability of the spillovers (χ) on the estimated value of the Verdoorn coefficient. Figures 4.16, and respectively present the estimated value of the Verdoorn coefficient, its Student t statistic and the corrected R^2 for the various specifications of the two parameters.

The previous sub-section highlighted the significant but transitory effect of strengthening the selection mechanisms on productivity dynamics. As shown by Figure 4.16, increasing the sensitiveness of the selection process, has a positive effect on the estimated values of the coefficient of the Law.

A strong selection process mechanically increases the aggregate productivity dynamics, giving more weight to the most dynamic firms. This effect is then disclosed, through the estimates of the Kaldor-Verdoorn Law, into a

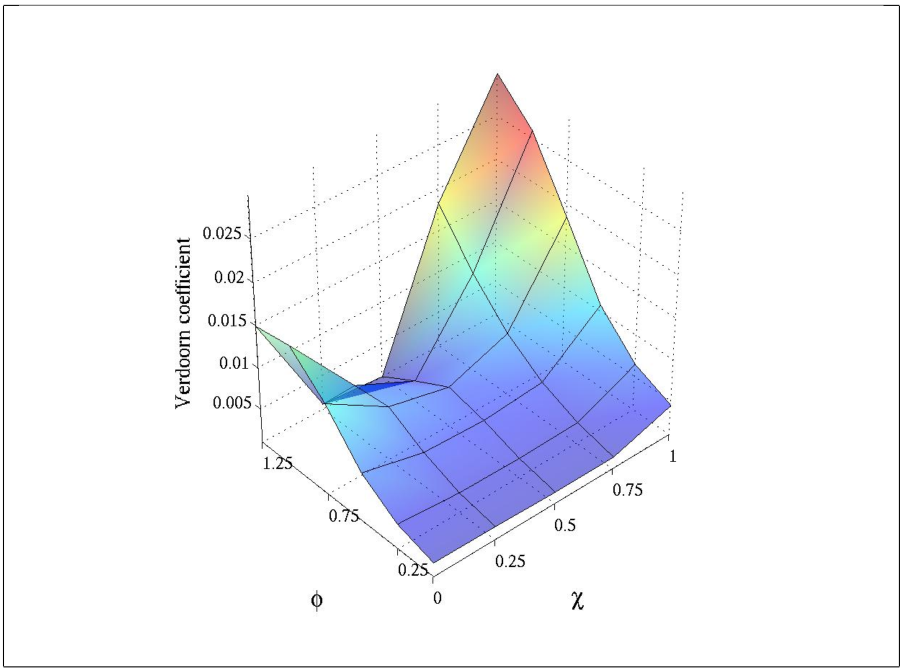

Figure 4.16: Estimated Verdoorn coefficient (50 steps growth rates), ϕ vs. χ

higher the level of increasing returns. A more striking results also comes out from the estimations of the Law. Changes in the parameter χ positively and significantly affect the estimated value of the coefficient. Hence, favouring imitation favours increasing returns.

Figure 4.17 presents the value of the Student t statistics for the estimated Verdoorn coefficients. These measure the level of significance of the coefficient. Except for the highest values of ϕ, all the estimated coefficient are significantly higher then zero. Note, however, that the value of the statistic decreases as χ increases. A stronger selection mechanism, limits mechanically the number of firms able to generate technical change. The aggregate productivity growth is then more sensitive to the stochastic nature of the shock. The outcome of the estimations is then less significant.

The outcome in terms of the value of the corrected R^2 presented in Figure 4.18 corroborate this result. As the selection mechanism gets stronger, the value of this statistic decreases. The Law therefore looses its explanatory power. The changes in the parameter χ do not exhibit a clear effect on the two statistics.

Result 7 *Enforcing the selection mechanisms significantly affects the Kaldor-Verdoorn Law. It favours, as imitation mechanisms, the diffusion of technological shocks this increase the value of the estimated coefficient. A stronger*

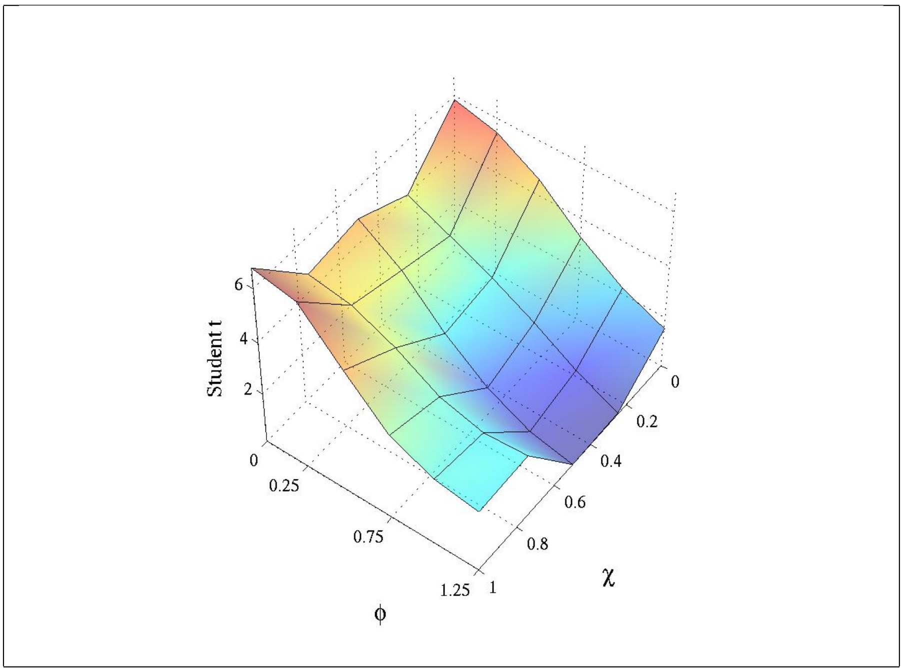

Figure 4.17: Student t for the Verdoorn coefficient (50 steps growth rates), ϕ vs. χ

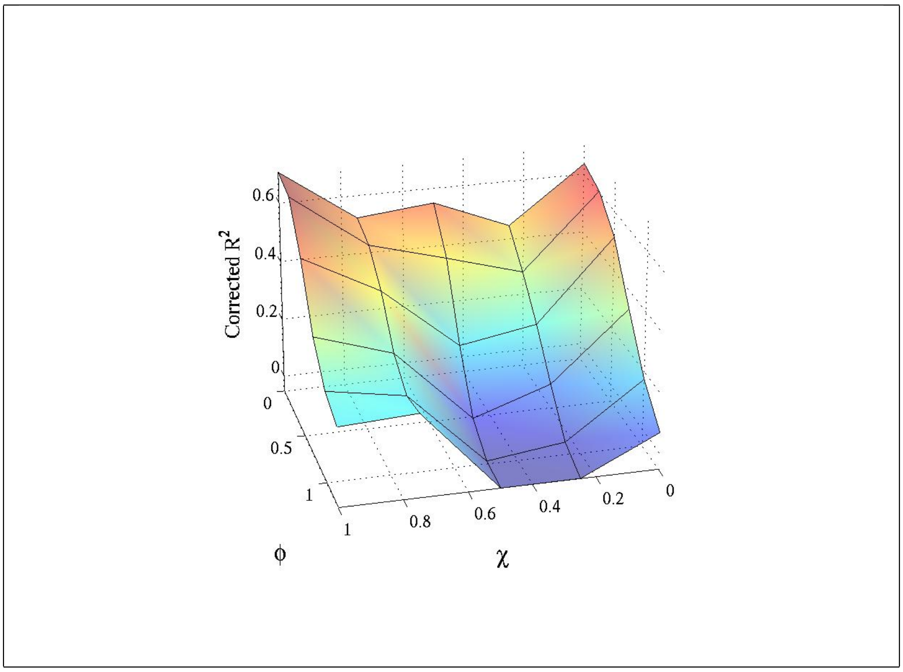

Figure 4.18: Corrected R^2 (50 steps growth rates), ϕ vs. χ

selection mechanisms limits the number of active firms. This limits the frequency of the technical change and therefore reduces the significance and explanatory power of the Law.

To briefly summarise this sub-section, the estimations show that the factors affecting the aggregate productivity significantly affect the Kaldor-Verdoorn Law. On the one hand the factors favouring the frequency or persistency of technological shocks positively the value and significance of the Verdoorn coefficient. On the other, the factors favouring the amplitude and the diffusion of the shocks positively affect the level of the increasing returns, although to the detriment of the significance of the coefficient. All the simulation results are summarised in Table 4.1

Table 4.1: Main Simulation Results

	$\nearrow \iota$	$\nearrow \sigma$	$\nearrow \frac{\Delta D}{D}$	$\nearrow \phi$	$\nearrow \chi$
Productivity level (500 steps)	$\searrow$	$\nearrow$	$\sim$	$\sim$	$\sim$
Productivity growth (50 steps)	$\searrow$	$\nearrow$	$\nearrow$	$\nearrow$	$\sim$
Verdoorn coefficient	$\searrow$	$\nearrow$		$\nearrow$	$\nearrow$
Student t	$\searrow$	$\searrow$		$\searrow$	$\sim$
Corrected R^2	$\searrow$	$\searrow$		$\searrow$	$\sim$

4.3 Concluding Remarks

This chapter has developed a simple micro-founded model of technological change inspired by the evolutionary literature. We have aimed to identify some sources of the increasing returns observed at the aggregate level in the previous chapters. In this respect, we analyse the effects of changes in various micro-characteristics of the model on the productivity dynamics. More precisely, we focus on the role played by the parameters affecting three phases of the technological change, namely the emergence, adoption and diffusion of the technological shocks. This analysis highlights the importance of the frequency and amplitude of the technological shocks in shaping the aggregate productivity dynamics. Second, the simulation exhibits that the resources devoted to the adoption of these shocks only transitorily affect these dynamics. Similarly, the factors favouring the diffusion of these shocks, and particularly, the selection mechanism, have a significant but transitory effect on productivity dynamics.

In the second part of this work, we estimated the Kaldor-Verdoorn Law using the data generated by the simulations for the various specifications of the parameters. The Law is verified in most of the cases. Moreover the estimation showed that some of the micro-characteristics affect the value and significance level of the Verdoorn coefficient. On the one hand, increasing the amplitude of the shocks and the strength of the selection mechanisms, increases the values but decreases the significance of the coefficient. These losses in significance are respectively due to increase in the unevenness of the shocks, in the first case, and a reduction of the frequency of the shocks, in the second one. On the other hand, augmenting the resources devoted to R&D increases the frequency of the shocks, affecting positively the value and significance of the shocks.

The evolutionary micro-dynamics can therefore represents a possible micro-foundation of the Kaldor-Verdoorn Law. Some key parameters characterising these micro-dynamics have a direct influence on the values of the increasing returns as estimated through the law. This leads us to conclude that the sources of increasing returns at the aggregate level resides in the mechanisms controlled by these parameters, namely the frequency and amplitude of technological shocks, the diffusion through imitation and the selection process.

Simulation Settings

Table 4.2: Parameters settings (the values by default are in italic)

ι_i	0	0,1	*0,2*	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
σ	0,01 0,065	0,015 0,07	0,02 0,075	0,025 0,08	0,03 0,085	0,035 0,09	0,04 0,095	0,045 0,1	*0,05* -	0,055 -	0,06 -
$\frac{\Delta D}{D}$	0,001 0,012	0,002 0,013	0,003 0,0,14	0,004 0,015	0,005 0,016	0,006 0,017	0,007 0,018	0,008 0,019	0,009 0,02	*0,01* -	0,011 -
ϕ	0	0,25	0,5	0,75	*1*	-	-	-	-	-	-
χ	0	0,25	0,5	*0,75*	1	-	-	-	-	-	-
μ	1	-	-	-	-	-	-	-	-	-	-
w	1	-	-	-	-	-	-	-	-	-	-
$\bar{z}$	0,0001	-	-	-	-	-	-	-	-	-	-
D_0		-	-	-	-	-	-	-	-	-	-
$z_{i,0}$	0,05	-	-	-	-	-	-	-	-	-	-
$A_{i,0}$	1	-	-	-	-	-	-	-	-	-	-
$a_{i,0}$	1	-	-	-	-	-	-	-	-	-	-

Summary of the Results

This second part of our thesis focused on productivity dynamics, analysing the mechanisms behind the technological or supply-side components of the growth process. Most of the growth theories acknowledge the role of increasing returns in explaining gains in labour productivity, even if those theories diverge in the formal representations of these increasing returns.

The main aim of this second part is to bridge the macro-approach to increasing returns proposed by the cumulative causation theory to the micro-founded dynamics of increasing returns generated by the evolutionary modelling.

We first propose to empirically show that, despite the structural and technological changes occurred since the initial estimations realised by Verdoorn (1949) and Kaldor (1966), the Kaldor-Verdoorn Law can still be verified at both macro and sectoral levels.

We first estimated the Law at the macro-economic level using three different samples of countries: Kaldor's (1966) sample of 12 countries, the pre-1974 OECD member sample of countries, and a third sample adding to the previous one a selected number of Eastern European, Latin American and South East Asian countries. We used these samples to estimate the Law for five decades. The results from this empirical analysis are the following.

When the estimations are realised using Kaldor's sample of countries, the law does not hold any more from 1970 onwards. This result is in line with Boyer and Petit (1981, 1991), bringing supporting evidences that changes in both production and demand structures led to the disappearing of increasing returns as described by the Kaldor-Verdoorn Law. This result is, however, clearly disproved when we extend the sample of countries used to estimate the Law. The Law is verified from 1980 onwards when the sample used is extended to the entire pre-1974 OECD members. The law is verified after 1980. The law is always verified, from 1960 onwards, when estimated using the sample enlarged to newly industrialised economies from Latin America, South East Asian and to some Eastern European economies.

This evidence can be due to two possible explanations. The first one is related to "technical" reasons (i.e. the choice of the countries included in the sample) and in line with Rowthorn (1975) 's claim that there could be outliers that biases the results. The second one is linked to the division of labour and structural change occurring in the most advanced economies since 1970. These changes induced dramatic modifications in the specialisation patterns. We inferred that the sources of increasing returns from 1970 onwards are rather to be found in the peripheral countries. This might therefore explains why the law holds over the enlarged samples even after 1970. Further, we might conclude as well that the understanding of aggregate productivity dynamics is therefore tightly linked to the understanding of the macro-frame and its changes.

In the last section of Chapter 3, we estimated the Kaldor-Verdoorn Law for 56 sectors for the two last decades. The empirical analysis showed that for the two periods and the most of sectors, including the non-manufacturing sectors, the law significantly holds. The empirical analysis, however, showed an increase of the heterogeneity in the levels and significance of the estimated parameters of the law. Paradoxically, this heterogeneity does not correspond to the traditional distinction between manufacturing and non-manufacturing sectors as considered by Kaldor (1966). In some sense, this might somehow question the analysis presented by Boyer and Petit (1981, 1991).

Further, the results highlighted that some changes occurring in the estimated values of the Kaldor-Verdoorn Law's parameters at the aggregated level were not linked to a general trend found among all the sectors. The decrease observed in the estimated value of the Verdoorn coefficient seems rather to correspond to changes occurring in a limited number of sectors. This again stressed the importance of the macro-frame and its changes when analysing the aggregated productivity dynamics.

Chapter 4 has developed a simple micro-founded model of technological change inspired by the evolutionary literature. We draw upon this model to identify some sources of the increasing returns as represented by the Kaldor-Verdoorn Law. In this respect, we analyse the effects of changes in various micro-characteristics of the model on the estimates of the Law using the data generated with the simulation model. The results found can be summarised as follows.

The Law is verified in most of the cases. The empirical evidence has shown that some of the micro-characteristics significantly affect the value, significance and robustness of the estimates. On the one hand, increasing the amplitude of the technological shocks and the strength of the selection mechanisms makes the values to be higher, but it decreases the significance of the coefficient, and the robustness of the Law. These results are respectively due to the increase in the unevenness of the shocks, in the first case, and a reduction of the frequency of the shocks, in the second one. On the other hand, augmenting the resources devoted to R&D makes the frequency of the shocks to increase, affecting positively the value, significance and robustness of the estimated coefficients.

The evolutionary model might then represent a plausible micro-foundation of the Kaldor-Verdoorn Law. In line with this result, we choose to introduce this micro-model to formalise the technological dynamics within the macro-models developed in the next part of this thesis.

Part III

Macro-Constraints, Technical Change And Growth Rates Differences

Introduction

The aim of this third part is to propose a formal framework to investigate the sources and nature of growth rates differences across economies. These investigations make extensive use of theoretical models.

Contrary to Verspagen (1993) that proposes a Evolutionary re-reading of a cumulative causation model, incorporating explicit selection mechanisms but keeping the analysis at a macro-scale, the models developed below contain Evolutionary micro-foundations for technical change. These micro founded dynamics are integrated to macro-frames directly in-line with cumulative causation models. Hence, following the Evolutionary precepts we consider that technical change is a micro-process emerging from heterogeneous and bounded rational firms. These firms are subject to mutations, i.e. changes in their production processes through innovation or imitation. Mutations are path-dependant; technical change is a function of firms' technological history as well as their past performance, due to financial constraints. Finally firms are subject to a selection mechanism, this process ought to sort the most performing firms allocating them the highest market shares. This process is formally set at the macro-level in our frameworks.

Following the Post Keynesian approaches, the level of aggregate demand defines the aggregated level of firms' output. The demand dynamics therefore constrain the firms' production dynamics. The selection mechanisms are coupled to demand dynamics in allocation among firms. Second macro-component, wage dynamics affect directly firms' production costs and therefore their prices and competitiveness level. These two macro components therefore act on the micro-dynamics as macro-constraints. But as we see with the formal description of our various models, these macro-constraints themselves are directly affected by micro-dynamics. Our model therefore integrates to the evolutionary frame a set of feedback mechanisms from macro-to-micro but also from micro-to-macro. This part of our work presents three models illustrating the importance of these feedbacks in explaining growth rates differences across the economies.

Chapter 5 proposes a one-sector growth model were the macro-frame is directly inspired by the Dixon and Thirlwall (1975) or Thirlwall (1979) modelling of Kaldor's cumulative causation. Aggregate demand dynamics is there function of its external component through a multiplier deduced from the balance of payment constraint.

Chapter 6 extends the previous model introducing a multi-sectoral dimension to the balance of payment constraint based modelling of aggregate demand dynamics. Through this extension we aim to stress the role of sectoral specialisation in generating growth rate differences.

Finally Chapter 7 proposes to release the balance of payment constraint and introduces in demand dynamics sectoral interdependencies of demand as well as satiation levels. Through this we aim to stress the importance of the sectoral structure of economies as well as there changes in explaining growth rates differences, this also allows us to relativise some results previously found.

Chapter 5

Balance of Payment Constraint and Growth Rate Differences

The purpose of this chapter[1] is to build a simple model, integrating some of the main features discussed previously and focusing its application to the growth rate divergence among integrated economies. It constitutes a baseline model for all the developments conducted in the coming chapters of this thesis.

This simple one-sector model relies on Kaldor's cumulative causation approach to growth mechanisms. The main aspect of Kaldorian approaches (Kaldor (1972, 1981) ; Dixon and Thirlwall (1975) ; Verspagen (2002)) is essentially based on two principles : First output growth is driven by the growth of aggregate demand, so that growth and technological progress are demand-driven processes. In Kaldor's mind this aggregate demand factor driving growth is concretely represented by the growth of exports that are driven by the country's degree of international competitiveness. Formally GDP growth rate is deduced from the balance of payment constraint, including then all these elements. Second, productivity is a "by-product of output"; this is due to the existence of dynamic increasing returns through the Verdoorn law and the mechanisms underlying it. The interrelation between these two mechanisms, growth rates tends, through the circular and cumulative mechanisms, to be maintained or increased over time. The main drawbacks of the approach is the "Kaldor-Verdoorn black box". We choose to open this box and substitute it with a micro-founded technical change, using an evolutionary model of industrial dynamics à la Nelson and Winter (1982). The main task is here to model the innovation process to endogenies the evolution of productivity. In other words we choose to close the model

[1] This chapters draws upon the model presented in Llerena and Lorentz (2004b).

with a micro-founded alternative to the Kaldor-Verdoorn Law, as the one developed in Chapter 4.

Our model then preserves one of the major feature of the different approaches it combines : unlike new growth theories, it never assumes full employment, and never considers a general equilibrium framework for analysing growth. It means that it never assumes the existence of a natural rate of growth along a given balanced growth path. The growth process is cumulative in this analysis because "growth creates the necessary resources for growth itself"[2]. This cumulative process allows an endogeneity of growth through growth itself as a self-reinforcing process.

The next section is devoted to a presentation of the model, followed, in section 6.2, by the development both of the main results and of their interpretations.

5.1 A Growth Model with Integrated Economies:

In order to consider the co-evolution of these components, we assume that aggregate demand is defined at the macro-economic level, through the balance of payment constraint. First, demand provides the necessary resources for firms to finance their activities and development (through both R&D and investments). Second, selection among firms takes place at the macro-economic level, as resulting from international competition. Firms located in a given country compete among themselves and with foreign firms on an integrated market[3]. Hence the macro-dynamics can be considered as a constraint on firm micro-dynamics.

On the other hand technical change, a necessary engine for growth, is rooted in firms' dynamics. The competitiveness of the entire economy relies on the firm's ability to generate technological progress. In other words, firms contains the essence of macro-dynamics.

As a consequence, micro and macro-dynamics are strongly interrelated. In this section we first present the macro-frame, then the micro-dynamics of firms.

The structure of the model can be described as follows: We consider a set of C economies integrated in an economic system through trade relations. An economy $c \in [1; C]$, is referred to with the index c. When variables are indexed w, they concern the foreign economies with regard to the economy c.

[2] León-Ledesma (2000)

[3] Assuming then neither trade limitations nor barriers to access foreign markets

Each economy counts I firms. A firm $i \in [1; I]$, based in the economy c is referred to with the indexes i, c. The entire economic system then counts C economies and $C * I$ firms. The index t refers to the time step.

5.1.1 Defining the macro-economic framework:

We suppose that the economies under-consideration are part of an integrated system constrained by the balance of payment with fixed exchange rates (or a common monetary system). Moreover, we assume that the member countries of the integrated system external debt with other members is restricted[4]. Given the monetary integration, the balance of payment adjustments through monetary mechanisms (exchange rates) are excluded and the balance of payment constraint corresponds then to a clearing of countries trade balance. In other words imports have to match exactly exports, for each integrated economy.

The macro-economic framework we develop here is directly rooted in the formal interpretation of Kaldor's cumulative causation approach of economic growth. These formal representations can be found among others in Dixon and Thirlwall (1975), or more recently Amable (1992), Verspagen (1993) and León-Ledesma (2000).

Economic growth is driven by demand. Aggregate demand is a function of an autonomous component, represented by external demand, i.e. countries' exports. For each economy, exports are given as a function of the income of the rest of the world and of the market share of the economy.

Balance of payment constraint and aggregate demand:

Exports for a given economy c is given by :

$$X_{c,t} = (Y_{w,t})^{\alpha_c} z_{c,t} \tag{5.1}$$

where $Y_{w,t}$ represents the GDP of the rest of the world[5], $z_{c,t}$ represents the market share of the economy, on the international markets and α_c income

[4]To simplify the model, we exclude the possibility for economies to rely on the external debt.

[5]Note that this variable is composed of the GDP level of all the other economies being part of this "integrated system" to which we add an exogenous component growing at a given and fixed level. The latter represents in some sense an additive demand that comes from outside the "integrated system", when running simulation we will however set the initial value of this variable such as in level it represents a marginal share of the "rest of the world GDP". Note that for technical reasons we use during the simulation this variables with a one period time lag.

elasticity to exports for the rest of the world.

The market share of the economy is a function of the price competitiveness of the country. In other words if the first component of the export function represents the income determinant of exports, the market share then represents the price component of external demand. The economy's market share is given by the sum of the market shares of the domestic firms (denoted $z_{i,c,t}$) :

$$z_{c,t} = \sum_i z_{i,c,t}$$

Each firm's market share is defined through a replicator dynamics[6], a function of a firm's relative competitiveness. Hence the market share of each firm will be computed as follows :

$$z_{i,c,t} = z_{i,c,t-1} \left(1 + \phi \left(\frac{E_{i,c,t}}{\bar{E}_t} - 1\right)\right) \tag{5.2}$$

where $z_{i,c,t}$ represents the market share of firm i, $p_{i,c,t}$ the price of its product, $E_{i,c,t}$ stands for firm i's level of competitiveness:

$$E_{i,c,t} = \frac{1}{p_{i,c,t}}$$

$\bar{E}_t$ the average competitiveness on the international market, given by:

$$\bar{E}_t = \sum_{c,i} z_{i,c,t-1} E_{i,c,t}$$

The parameter $\phi \in [0;1]$ measures demand rigidity to price changes. The more ϕ tends to 0 the more rigid demand is with respect to price competitiveness changes.

To complete the formal definition of the macro-economic framework, we have to define the economy's imports. They are basically defined following exports' scheme, as a function of the domestic economy income and of the rest of the world's market share. Formally imports will be represented as follows:

$$M_{c,t} = (Y_{c,t})^{\beta_c}(1 - z_{c,t}) \tag{5.3}$$

The parameter β_c represents the income elasticity to import. $Y_{c,t}$ corresponds to the domestic aggregate demand, itself equal to the gross product of the economy.

[6]For a comprehensive view on the use of the replicator dynamics in evolutionary economics see Metcalfe (1998)

We assume that each economy has to satisfy the balance of payment constraint. In our model this corresponds to an equilibrated trade balance. An economy c's external expenditures have to match exactly its external resources. In terms of growth rate the balance of payment constraint can then be represented as follows:

$$\frac{\Delta M_{c,t}}{M_{c,t-1}} = \frac{\Delta X_{c,t}}{X_{c,t-1}} \tag{5.4}$$

with:

$$\frac{\Delta X_{c,t}}{X_{c,t-1}} = \alpha_c \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \frac{\Delta z_{c,t}}{z_{c,t-1}} \tag{5.5}$$

$$\frac{\Delta M_{c,t}}{M_{c,t-1}} = \beta_c \frac{\Delta Y_{c,t}}{Y_{c,t-1}} - \frac{z_{c,t-1}}{1 - z_{c,t-1}} \frac{\Delta z_{c,t}}{z_{c,t-1}} \tag{5.6}$$

Using the balance of payment constraint we can then deduce the economies' aggregate demand growth rate as function of the rest of the world income and of the economy's market share dynamics:

$$\frac{\Delta Y_{c,t}}{Y_{c,t-1}} = \frac{\alpha_c}{\beta_c} \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \frac{e_{c,t-1}}{\beta_c} \frac{\Delta z_{c,t}}{z_{c,t-1}} \tag{5.7}$$

With

$$e_{c,t-1} = \frac{1}{1 - z_{c,t-1}}$$

The growth rate of market shares can be deduced from equation 5.2, we then obtain the following expression for the GDP growth rate. With this last representation we can clearly distinguish the effect of external demand from the effect linked to the micro-dynamics:

$$\frac{\Delta Y_{c,t}}{Y_{c,t-1}} = \frac{\alpha_c}{\beta_c} \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \phi \frac{e_{c,t-1}}{\beta_c} \left(\frac{E_{c,t}}{\bar{E}_t} - 1 \right) \tag{5.8}$$

The first component of the right end side of the equation captures in fact Harrod's trade multiplier. Hence GDP growth rate in our model will be defined through the trade multiplier and through a second component linked to the competitiveness of the economy. This second component captures the micro-dynamics, and especially the effect of technical change arising at the micro-level and influencing the directly competitiveness of the economy.

We can deduce from the expression for GDP growth rate the GDP level at time t. It equals the domestic aggregated demand. GDP is given by:

$$Y_{c,t} = Y_{c,t-1} \left[1 + \frac{\alpha_c}{\beta_c} \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \phi \frac{e_{c,t-1}}{\beta_c} \left(\frac{E_{c,t}}{\bar{E}_t} - 1 \right) \right] \tag{5.9}$$

This expression also represents the gross production of all firms at time t. In our model, the time dimension allows aggregate supply to match entirely aggregate demand. We do not consider here explicitly the process of coordination of demand and supply in the market for goods.

Aggregate (economy wide) demand is then distributed among the firms in the economy given their market shares on the integrated markets. It constitutes the first macro-economic constraint the firms have to face.

Wage dynamics:

The second macro-economic component of our model affecting firms' dynamics are wages. These are set at the macro-level. Wage dynamics is correlated to the average labour productivity growth rate of an economy as defined in the following expression:

$$w_{c,t} = w_{c,t-1} \left(1 + \gamma \frac{\Delta A_{c,t}}{A_{c,t-1}}\right) \tag{5.10}$$

$A_{c,t}$ represents the average labour productivity level of the economy c at time t.

The parameter $\gamma \in [0;1]$ weights the effect of labour productivity growth on wage dynamics. When $\gamma = 1$, wages are perfectly correlated with productivity growth. In this case wages gradually absorb the productivity gains effect on firms' competitiveness. When $\gamma = 0$, productivity growth has no impact on wages. Its effect on competitiveness won't be absorbed by wages. As no other variables is considered here as affecting wages, these remain fixed in this case.

The linkages between wages, productivity and competitiveness imply that when γ is unitary, firms competitiveness is rather determined with respect to the firms relative productivity gains (with respect to the average). While, when γ is null, firms' competitiveness relies on their absolute productivity gains. As we discuss later on, the wage regime has a direct impact on the transmission of micro-level technological shocks to macro-dynamics. Wages are not only a factor affecting firms but a major channel linking the micro to the macro dimensions.

5.1.2 Evolutionary micro-foundations of technical change.

This second level of the model concerns firms and industrial dynamics. We explain here firms' behaviour and characteristics. This part is largely inspired by the model developed in Chapter 4. We assume here that each economy is represented by a population of bounded rational firms. These firms mutate, by learning about the production process to improve their productivity.

Firms will have two distinct but complementary roles in our model. First they produce the necessary resources to sustain economic growth, by responding to the demand needs. Second they increase the competitiveness of the economy by trying to improve their productivity level to survive the selection process. This second process will be broken down into two stages:

- Exploration or R&D. Firms first search for new production facilities, through innovation or adaptation of existing production facilities. The outcome of the R&D process is uncertain, and defines efficiency (in terms of productivity) of the new generation of capital goods.

- Exploitation of R&D outcome. This second stage requires that firms invest to incorporate the outcome of research in the production process.

These two stages are financed by profits, and then directly subject to the success of previous investments. Formally the micro-level of the model draws largely on the one developed in Chapter 4

Firms characteristics:

Firms' production processes are represented by Leontiev production functions with labour as a unique production factor. Capital enters indirectly in the production function by influencing labour productivity. Investment in the different generations of capital goods will increase labour productivity. The production function will then be represented as follows :

$$Y_{i,c,t} = A_{i,c,t-1} L_{i,c,t} \tag{5.11}$$

where $Y_{i,c,t}$ is the output of firm i, producing in country c at time t. $A_{i,c,t-1}$ represents labour productivity and $L_{i,c,t}$ the labour force employed in the production process. The output is constrained by the demand directed at the firms and defined at the macro-economic level. The level of production of each firm is computed as a share of GDP given by their relative market shares such as:

$$Y_{i,c,t} = \frac{z_{i,c,t}}{z_{c,t}} Y_{c,t}$$

Labour productivity is a function of the firms' accumulated generations of capital goods through investment:

$$A_{i,c,t} = \frac{I_{i,c,t} a_{i,c,t-1}}{\sum_{\tau=1}^{t} I_{i,c,\tau}} + \frac{\sum_{\tau=1}^{t-1} I_{i,c,\tau}}{\sum_{\tau=1}^{t} I_{i,c,\tau}} A_{i,c,t-1} \tag{5.12}$$

where $a_{i,c,t-1}$ represents the labour productivity embodied in the capital good developed by i during period $t-1$. $I_{i,c,t}$ represents the level of investment in capital goods of the firm. This component will be explained later. Firms set prices through a mark-up process. This mark-up is applied to the production costs (i.e. labour cost). To simplify the model, labour costs linked to R&D activity are financed by profits. Thus prices can be represented as follows:

$$p_{i,c,t} = (1 + \mu_c) \frac{w_{c,t-1}}{A_{i,c,t-1}} \tag{5.13}$$

where $p_{i,c,t}$ represents the price set by firm i at time t, μ_c the mark-up coefficient and $w_{c,t-1}$ the nominal wage set at the macro level as defined above. It should be noted that we assume here that the mark-up coefficients are fixed for each firms in a given economy. This insures that the share of profits in GDP is constant over time, which corresponds to one of Kaldor's stylised facts.

The firm's profit level is then be computed as follows:

$$\Pi_{i,c,t} = p_{i,c,t} Yi,c,t - w_{c,t-1} L_{i,c,t} = (1 + \mu_c) \frac{w_{c,t-1}}{A_{i,c,t-1}} Y_{i,c,t} - w_{c,t-1} \frac{Y_{i,c,t}}{A_{i,c,t-1}}$$

$$\Pi_{i,c,t} = \mu_c \frac{w_{c,t-1}}{A_{i,c,t-1}} Y_{i,c,t} \tag{5.14}$$

In the model profits constitutes the only financial resource for firms' investments.

To improve their competitiveness and thus gain some market shares firms have to improve their production processes (i.e. to increase labour productivity). The process of technical improvement can be divided into two distinct phases. Firms explore new technological possibilities, through local search (innovation) or by capturing external technological possibilities (through spill-overs). This process leads to a production design (or capital good design) that can be exploited by firms in their production process. The second stage consists then in the exploitation of the design by incorporating it as a new generation of capital goods. The exploitation process is related to investment in capital goods and the exploration is related to investments in research. We assume that a priority is given to investments, and therefore the exploitation of already discovered technologies.
Investment in capital goods is financed by the profits of the firm, using a share $\iota_{i,c}$ of sales. Investment is subject to a financial constraint. Hence, as investments are completely financed by profits, they cannot exceed the period's profit level. Formally this constraint will be represented as follows:

$$I_{i,c,t} = min \left\{ \iota_{i,c} Y_{i,c,t} \ ; \Pi_{i,c,t} \right\} \tag{5.15}$$

The resources available for investment depend on firms' profits and therefore on the outcome of their previous performances. The model, here, takes into account the sequential nature of the decision process and the existence of a financial constraint linked to the success (or failure) of firms. In this respect the model includes to its evolutionary micro-foundations an additional "Austrian flavour".[7] Investments in R&D are a share $\rho_{i,c}$ of their sales. R&D investment will correspond to the hiring of workers assigned to the research activity :

$$R_{i,c,t} = \frac{1}{w_{c,t-1}} \min\{\rho_{i,c} Y_{i,c,t}; \Pi_{i,c,t} - I_{i,c,t}\} \tag{5.16}$$

The formalisation of the R&D process is explicitly inspired by evolutionary modelling of technical change. Hence following Nelson and Winter (1982) we will consider that the probability of success of research is an increasing function of R&D investments. Formally the R&D activity is represented by the following procedure:

1. Firms draw a number from a uniform distribution on [0 ; 1].
2. If this number is contained in the interval $\left[0\ ;\ \frac{R_{i,c,t}}{Y_{i,c,t}}\right]$, the R&D is successful.
3. If R&D is successful, its outcome is defined through the following stochastic process. We differentiate here explicitly innovative firms from imitative ones:

$$a_{i,c,t} = \max\left\{a_{i,c,t-1} + \epsilon_{i,c,t}; a_{i,c,t}\right\} \tag{5.17}$$

$$\epsilon_{i,c,t} \sim N(0; \sigma_{i,c,t}) \tag{5.18}$$

$$\text{with} \begin{cases} \sigma_{i,c,t} = \sigma_c & \text{if the firm is an innovator} \\ \sigma_{i,c,t} = \chi(\bar{a}_t - a_{i,c,t}) & \text{if the firm is an imitator} \end{cases} \tag{5.19}$$

The outcome of the R&D process defines the labour productivity embodied in the newly discovered capital vintage ($a_{i,c,t}$). $\bar{a}_t$ represents the average productivity level embodied in the latest capital vintages developed by firms. It is formally computed as:

$$\bar{a}_t = \sum_{c,i} z_{i,c,t} a_{i,c,t-1}$$

For innovators the R&D activity therefore resorts to 'local searching' as defined by Nelson and Winter (1982), while imitators try to reduce their technological gap adopting existing technologies.

[7]See Amendola and Gaffard (1998), p.126)

Firms exit the market if their market share is lower then $\bar{z}$. They are replaced by firms characterised by the average values of the technological variables within the economy of these exiting firms and a market share equal to $\bar{z}$. In this respect the number of firms remains constant. An innovator that exits is replaced by an innovator, and an imitator by an another imitator. The proportion of innovators (imitators) therefore remains constant.[8]

5.2 Growth Rate Difference Among Integrated Economies : Main Simulation Results

The model as developed in the previous section aims to consider the determinants of possible difference in GDP growth rates among integrated economies. Traditionally, mainstream economics considers that the integration of economies and openness to trade imply convergence due to the diffusion of knowledge and/or technologies.

For Neo-Schumpeterian evolutionary economics, growth rates differences depends on the balance between two effects :

- Innovation, heterogeneous among economies both in its timing and in the outcome, that increases differences in GDP growth rates, and

- Imitation that reduces this difference.

Hence in this framework growth rate divergence directly depends on the accessibility of technologies, innovation and imitation capabilities, and on the decision processes linked to R&D investment.

For the Kaldorian approach growth rate difference is structural depending on both demand and technological parameters, and cumulative, due to the emergence of vicious and virtuous circles.

As for most of the models incorporating evolutionary features we need to resort to numerical simulations[9]. Simulations are set through the following scheme. We consider 5 economies, each of which counts 20 firms. All the firms of a given economy are equally defined (same initial conditions and parameters). The details of the parameters values used can be found in Table 5.2 and 5.3.

Our analysis focuses on the determinants of growth rate differences among the economies composing our artificial system. The aim of the exercise is to

[8]This proportion is set to 50% for the simulations

[9]We used LSD (Laboratory for Simulation Development) environment to implement the simulations. The source code for the model can be available on request to the authors

highlight the existence of different and complement sources driving to specific divergence patterns. We therefore investigate a set of key parameters directly linked to the sources of growth as identified by the cumulative causation and the evolutionary literature, namely technology and demand, present at the micro and macro-levels:

Four of these parameters concern the macro-frame:

- α_c and β_c, respectively the income elasticity to exports and income elasticity to imports. These parameters define the trade multiplier effect affecting directly the influence of foreign income on domestic income growth rates.

- ϕ, the price elasticity. This parameter affects the speed (or strength) of the selection process as described by the replicator equation.

- γ; this parameter weights the influence of productivity increases on wage dynamics. It therefore influences competitiveness, modifying the level of absorption of the technological shocks by wages.

None of these two last parameters directly generates differences among economies, but as we see below they are crucial in calibrating the strength of the selection mechanisms.

The two remaining parameters affect the micro-mechanisms generating technological change:

- $\bar{\sigma}_c$ defines the level of technological opportunities for the innovators. The higher $\bar{\sigma}_c$, the larger the possibilities of improving one's technology. Introducing heterogeneity among economies in terms of their technological opportunities should be a major source for divergence according to the Schumpeterians.

- χ_c defines the absorptive capacities of imitating firms. The higher χ_c, the larger imitators benefit from technological spillovers. This parameter affects directly the diffusion of technologies. This should limit the differences in growth rates among economies.

The main characteristic of the model is to generate distinct divergence regimes:

- *Sustained growth rate differences*. This regime is characterised by economies growing in parallel at different rates. This regime emerges with the introduction of heterogeneity in income elasticities. This regime do not necessary imply significant differences in technologies.

- *Transitory growth rate differences.* This regime is characterised by transitory phases of divergence. This pattern emerges with the introduction of heterogeneity in technological opportunities. Its transitory nature is related to specific settings of the wage dynamics.

- *Destructive growth rate divergence.* In this case growth rate difference increases over time until the collapse of the lagging economies. This regime is characterised by the emergence of a technologically dominant economy. This regime emerges when wage dynamics do not absorb at all technological shocks, leading the best technology firm and economy to dominate the markets.

The key results of the simulations are detailed below. The results presented for every configurations represent the average outcome over 20 simulation runs. We aim, this way, to insure the representativeness of the results presented. Differences in GDP and productivity growth rates are measured using the coefficient of variation of these variables among the 5 economies.

5.2.1 Selection and growth rates differences

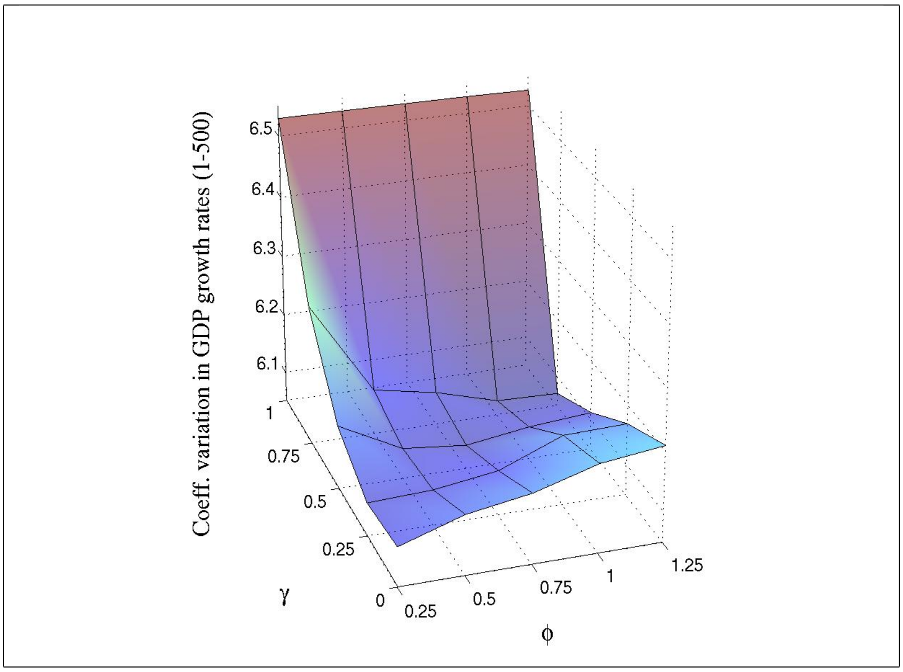

Figure 5.1: Differences in GDP growth rates with changes in γ and ϕ

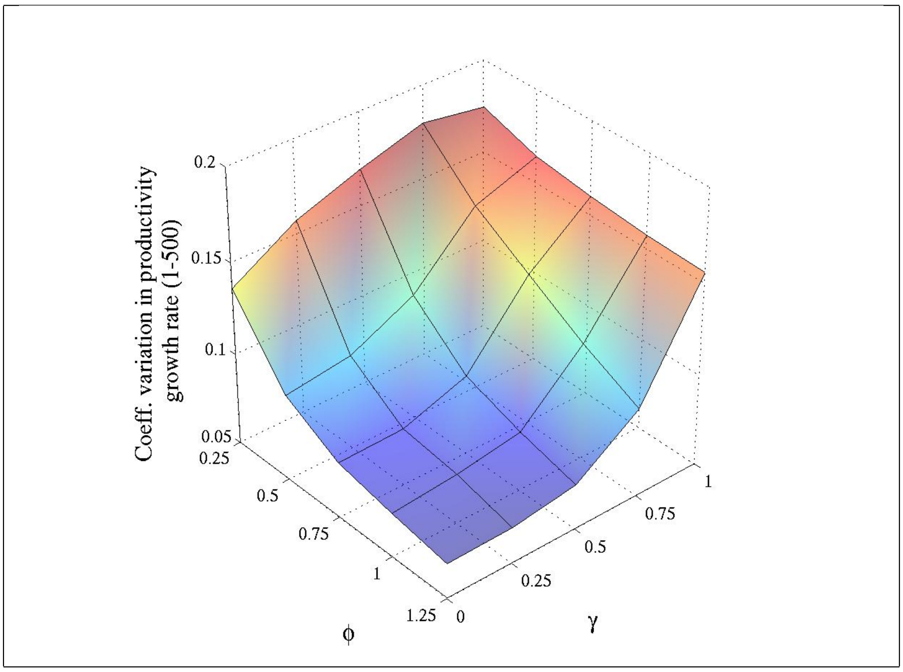

Figure 5.2: Differences in productivity growth rates with changes in γ and ϕ

This subsection presents the results generated by the simulations considering the effects of selection related parameters on growth rates differences. These results are reported in Figures 5.1 and 5.2.

Figure 5.1 presents the average coefficient of variation in GDP growth rates over the 500 simulation steps for different settings of price elasticity ϕ and γ. Note that these settings imply that all economies are initially similar. None of the two parameters directly generates differences among economies. The differences emerging along simulations are directly due to the stochastic nature of the technical change. Figure 5.1 not only shows that some significant differences exist among economies, but also exhibit an interesting feature of the wage adjustment process. Hence when wages dynamics is highly correlated to productivity increases, variations in the strength of the selection process (increasing ϕ) has no significant effect on growth rates differences. While for small values of γ, the strength of selection significantly increase the differences in growth.

On the other side, as depicted in Figure 5.2, reinforcing selection decreases the differences in productivity growth. Similarly these differences reduce when decreasing γ. Hence these two parameters directly influences the amplitude of the selection mechanisms and its effect on the macro-dynamics.

But wage adjustment process seems however to play a crucial role in the transmission of the divergence pressures emerging from the stochastic and intrinsically uneven nature of technical change from the micro to the macro dynamics. It leads to more drastic patterns when this nature is amplified as seen in the last subsection.

5.2.2 Demand characteristics and growth rate differences

This second subsection presents the results generated by the model when introducing heterogeneity in income elasticity.

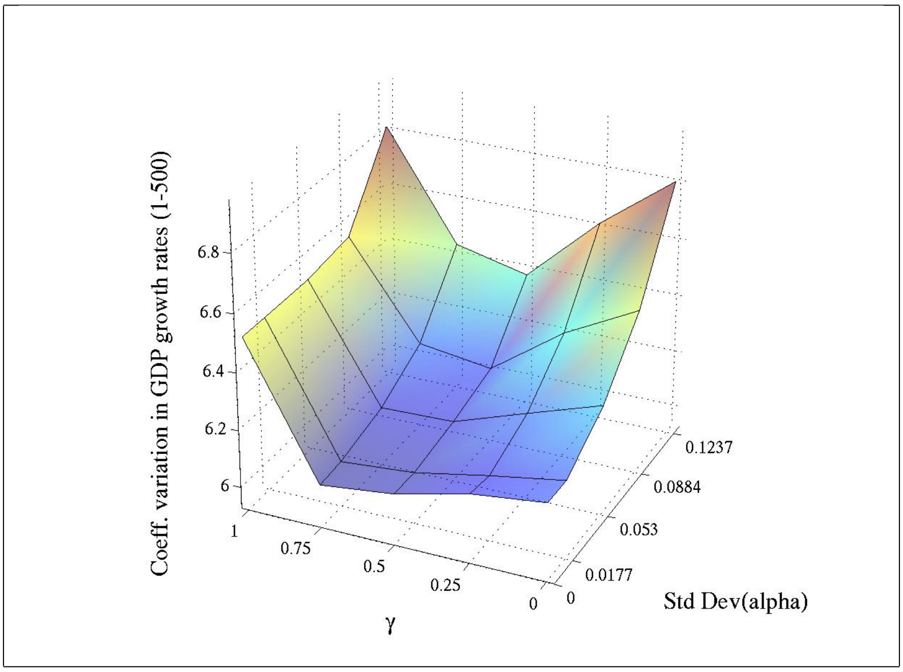

Figure 5.3: Differences in GDP growth rates with heterogeneous α_c and changes in γ

Result 8 *Increasing the heterogeneity in income elasticity to exports α_c significantly increases the differences in GDP growth rates essentially by affecting the trade multiplier. The differences generated are sustain over time, without generating vicious circles.*

This effect on growth rate difference is perfectly predictable. It results from the trade multiplier component of the model. Heterogeneity in income elasticity implies differences in the trade multiplier. This factor mechanically generates differences in GDP growth rates regardless any other factors, including technology. In this case the divergence pattern is entirely demand driven.

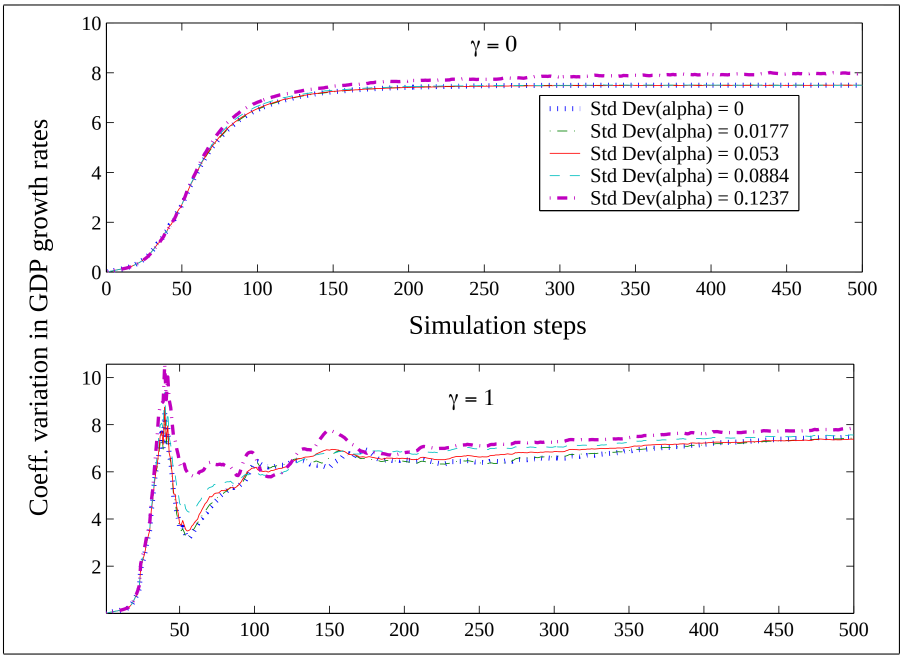

Figure 5.4: Differences in GDP growth rates with heterogeneous α_c.

As depicted in Figure 5.4, these difference in GDP growth rates are permanent. The sustainability of this differences is principally due to the effect on the trade multiplier. This result is directly in-line with the cumulative causation literature. Figure 5.5 presents an example where economies grow parallel to each others at different rates. The emergence of a dominant economy is not detrimental to the others. Each economy grows at its own rate, defined by the trade multiplier.

The differences in resources induced by the differences in aggregate demand generated through time by heterogeneous demand parameters are not sufficient to observe significant differences in technology levels (see Figure 5.6).

To summarise heterogeneity in demand characteristics generates significant differences in growth rates but is not sufficient to generate significant differences in technologies among economies. Similar patterns emerge when introducing heterogeneity in β_c, as presented in Figure 5.7. In both cases divergence is not induced by, or coupled with the collapsing of economies (i.e the existence of vicious circles).

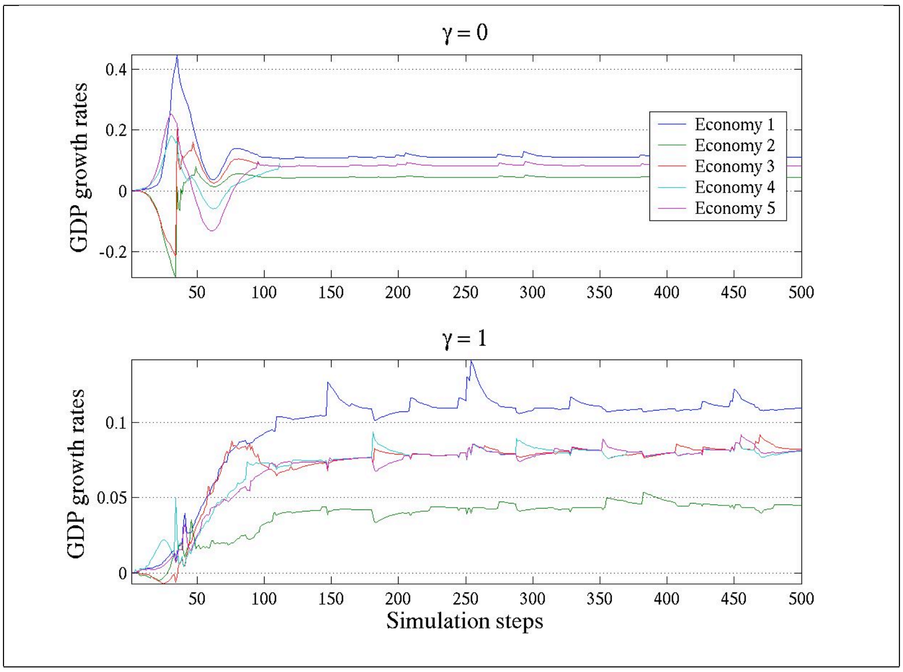

Figure 5.5: GDP growth rates with heterogeneous α_c.

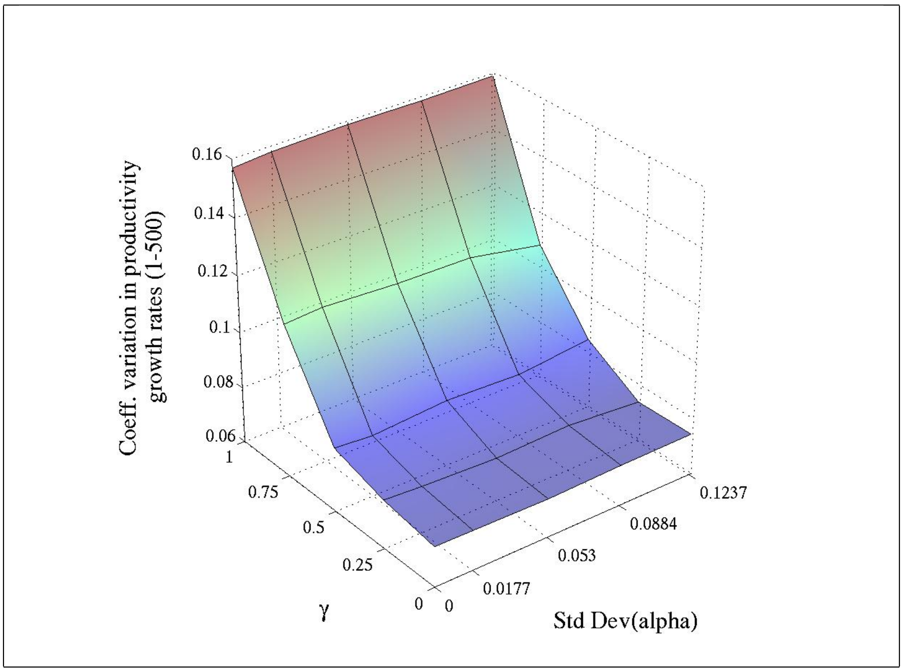

Figure 5.6: Differences in productivity growth rates with heterogeneous α_c and changes in γ

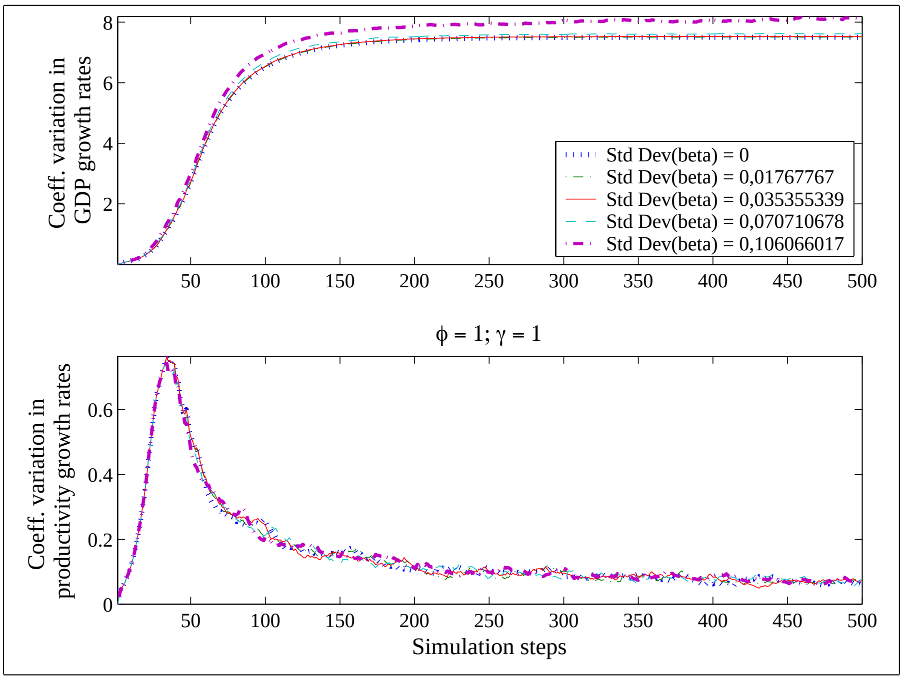

Figure 5.7: Differences in GDP and productivity growth rates with heterogeneous β_c

5.2.3 Technology and growth rate divergence.

The second set of parameters considered in this analysis concerns the technological characteristics of the economies. Theses are represented here by the range of technological opportunities ($\bar{\sigma}_c$) and absorptive capacities (χ_c), assuming that the economies are identical with regard to the initial conditions.

Result 9 *Increasing heterogeneity in technological opportunity parameter ($\bar{\sigma}_c$), significantly increases growth rate difference among economies for low values of γ. The differences generated are only transitory.*

Figure 5.8 presents the average differences in GDP growth rates over the entire simulations (from step 1 to 500). It clearly shows that increasing technological differences can significantly affect differences in growth rates for specific settings of the wage adjustment mechanisms. Wages play here the role of a catalyser for the effect of the micro-differences in technology on the macro-level dynamics.

As Figure 5.9 clearly shows, the effect of the technological heterogeneity on growth rates differences is actually limited to the first half of the simulation periode. The differences in GDP growth rates gradually fade away.

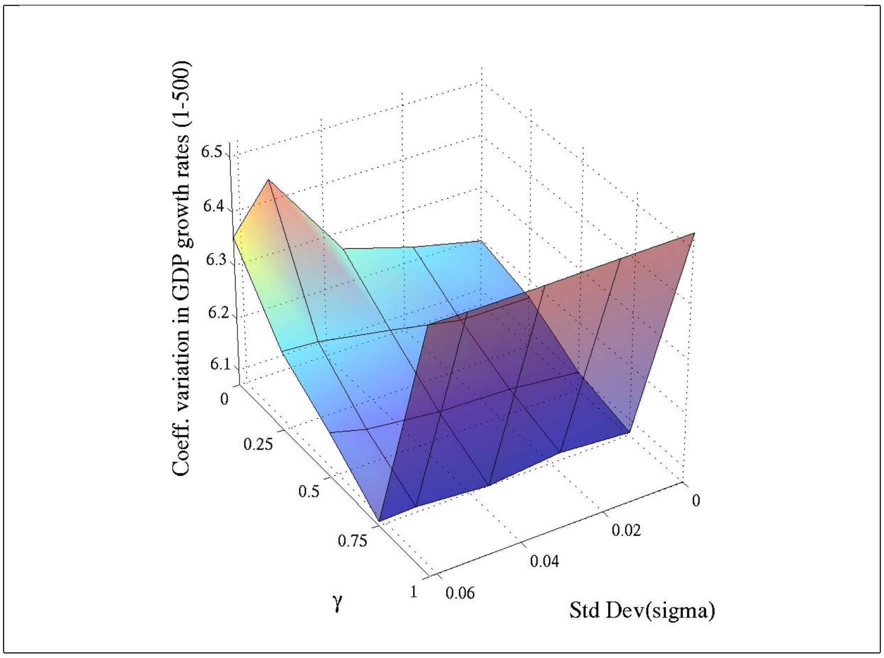

Figure 5.8: Differences in GDP growth rates with heterogeneous $\bar{\sigma}_c$ and γ

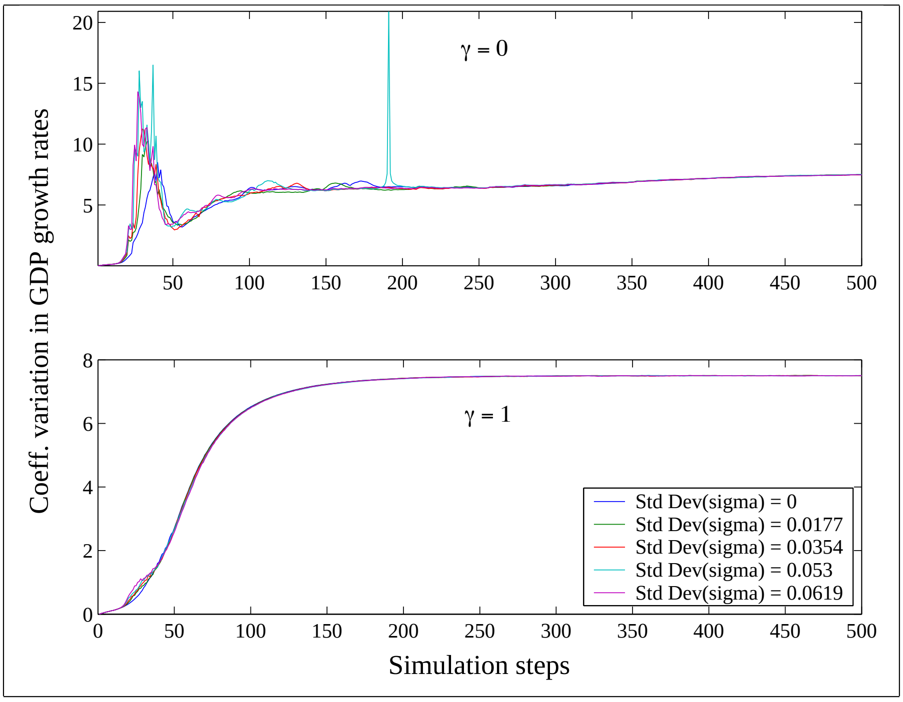

Figure 5.9: Differences in GDP growth rates with heterogeneous $\bar{\sigma}_c$

The transitory nature of these growth rates differences among economies can be expalined by the combiantion of two processes: First, the technological differences are gradually absorbed by wages affecting competitiveness through production costs and prices, and firms ability to innovate, increasing the cost of R&D. Second, the technological differences affect growth only through gains in competitiveness. Once an economy has become monopolist it can no more grow due to gains in market shares.

Figure 5.10 presents two example of simulation runs. These two examples illustrate two possible patterns generated by the introduction of heterogeneous technologies. When $\gamma = 1$, heterogeneous technological opportunities generates differences in productivity growth rates (see Figure 5.11), these generate differences in GDP growth rates (see the lower part in Figure 5.10), through changes in competitiveness. In this case transitory differences emerge but gradually fade and disappear.

Result 10 *Heterogeneity in technological opportunities can generate vicious circles for specific settings of wages' adjustment mechanisms.*

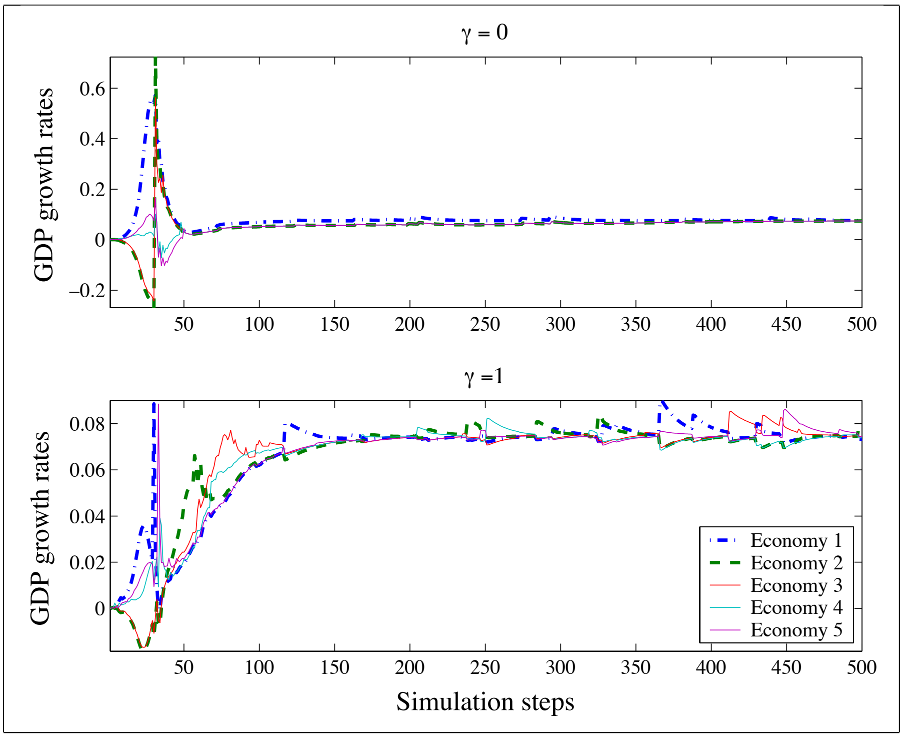

Figure 5.10: GDP growth rates with heterogeneous $\bar{\sigma}_c$.

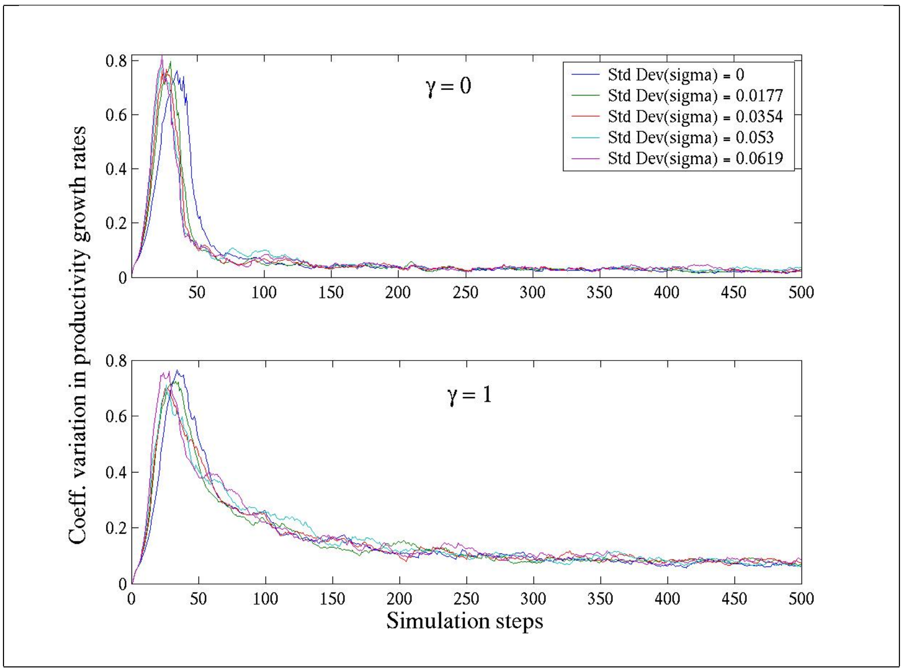

Figure 5.11: Differences in productivity growth rates with heterogeneous $\bar{\sigma}_c$

When $\gamma = 0$, the differences in productivity growth rates (see Figure 5.11), affect competitiveness, and therefore differences in GDP growth rates. In this case the increase in productivity is not absorbed by increase in wages, and the least favoured economy gradually disappear (see the upper part of Figure 5.10), without properly collapsing given the entry and exit process, but stuck with the lower bound market shares.

This last case can be interpreted as a "social dumping" situation, in which wages do not benefit from productivity gains. These gains only affect firm's profits. Contrary to the common thoughts, "social dumping" here, do not favour productivity gains for lagging economies on contrary it reinforces the differences, favouring the leaders and suffocating the others. Wages when absorbing productivity gains, on the contrary limit inter-economy differences, leading to the coexistence of economies with uneven productivity levels, but also uneven wage levels. Note however that this result hold if all economies apply the same rules (same γ) of wage determination.

Result 11 *Increasing absorptive capacities has no significant effect on differences in GDP growth rates among economies.*

As depicted in Figure 5.12, increasing the access to technological spillovers seems to significantly reduce the differences in productivity growth rates

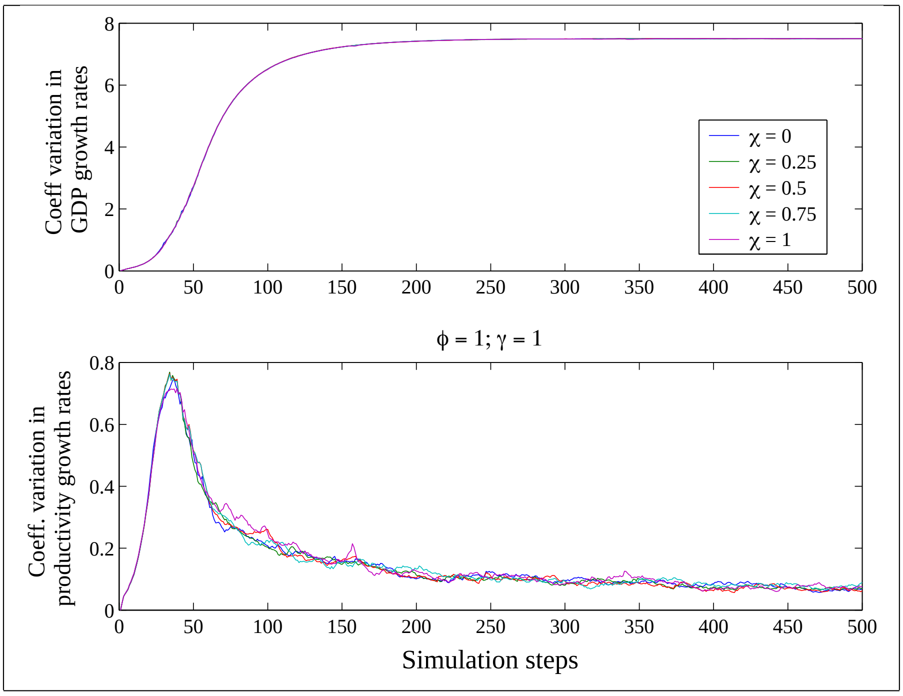

Figure 5.12: Differences in GDP and productivity growth rates with changes in χ

among the economies. It, however, do not affect significantly the differences in GDP growth rates among these.

Considering the technological sources of growth rates differences among economies, two significant regimes emerge from the simulations. These are both generated through the increasing of heterogeneity in technological opportunities. One is characterised by transitory phases of divergence due to technical change but these gradually fades ; the effect of technical change being absorbed by wages. The second is characterised by the emergence of vicious circles leading the least favoured economies to disappear. In this case wages are not absorbing technological shocks that therefore have drastic effects on macro-dynamics. The results obtained through simulations are summarised in Table 5.1

5.3 Concluding remarks.

Our aim along this chapter is to identify the sources of growth rates differences among economies. We address this question developing a theoretical model inspired by cumulative causation including an evolutionary micro-

Table 5.1: Main Simulation Results

	$\nearrow \phi$	$\nearrow StdDev(\alpha_j)$	$\nearrow StdDev(\bar{\sigma}_j)$	$\nearrow \chi$
Low γ	$\nearrow$ differences *"destructive divergence regime"*	$\nearrow$ differences	$\nearrow$ differences *"destructive divergence regime"*	no effect
High γ	$\searrow$ differences	$\nearrow$ differences *"sustained differences regime"*	$\nearrow$ differences *"transitory differences regime"*	no effect

founded technical change. We attempt here to open the 'Kaldor-Verdoorn Law black-box', introducing these micro-foundations in traditional Kaldorian frame. We focus our analysis on the effect of six key parameters :

- Income elasticities, considering then the effect of the demand structure on growth rate dynamics.

- Technological opportunities and absorptive capacity, considering the influence of technological change on growth rate dynamics.

- Price elasticity and the wage adjustment parameter, considering the effect of selection mechanisms as a catalyser for micro to macro-dynamics.

The simulations results allow us to sort out three distinct divergence regimes.

First, the model generates a regime of sustained growth rate differences. This regime emerges with the introduction of heterogeneity in income elasticities. This regime do not necessary imply significant differences in technologies.

Second, it generates a regime of transitory phases of divergence. This pattern emerges with the introduction of heterogeneity in technological opportunities. Its transitory nature is related to specific settings of the wage dynamics.

Third, a regime of destructive growth rate divergence emerges when wage dynamics do not absorb at all technological shocks, leading the best technology firm and economy to dominate the markets. In this case growth rate difference increases over time until the collapse of the lagging economies.

Hence, the introduction of evolutionary micro-foundations of technical change in a Kaldorian framework, allows for more subtle considerations in understanding growth rate difference among integrated economies. However, this model might constitute the starting point for further analysis. The way technical change is considered remains sketchy.

Simulations also highlight the crucial role played by the wage adjustment mechanisms as a catalyser for growth impulses from micro to macro. Similar results were found concerning the relationship between specialisation and growth differences in a multi-sectorial extension of this model developed in Chapter 6. Distinct regimes emerge, demand and technology driven. There again, the wage adjustment process allows the transmission of micro-shocks to macro-dynamics.

Simulation Settings

Table 5.2: Key parameters settings (the values by default are in italic)

	Economy 1	Economy 2	Economy 3	Economy 4	Economy 5
α_j	*0,375*	*0,375*	*0,375*	*0,375*	*0,375*
α_j	0,4	0,35	0,375	0,375	0,375
α_j	0,45	0,3	0,375	0,375	0,375
α_j	0,5	0,25	0,375	0,375	0,375
α_j	0,55	0,2	0,375	0,375	0,375
β_j	*0,5*	*0,5*	*0,5*	*0,5*	*0,5*
β_j	0,525	0,475	0,5	0,5	0,5
β_j	0,55	0,45	0,5	0,5	0,5
β_j	0,6	0,4	0,5	0,5	0,5
β_j	0,65	0,35	0,5	0,5	0,5
$\bar{\sigma}_j$	*0,1*	*0,1*	*0,1*	*0,1*	*0,1*
$\bar{\sigma}_j$	0,125	0,075	0,1	0,1	0,1
$\bar{\sigma}_j$	0,15	0,05	0,1	0,1	0,1
$\bar{\sigma}_j$	0,175	0,025	0,1	0,1	0,1
$\bar{\sigma}_j$	0,1875	0,0125	0,1	0,1	0,1
χ_j	0	0	0	0	0
χ_j	0,25	0,25	0,25	0,25	0,25
χ_j	*0,5*	*0,5*	*0,5*	*0,5*	*0,5*
χ_j	0,75	0,75	0,75	0,75	0,75
χ_j	1	1	1	1	1
γ	0	0	0	0	0
γ	0,25	0,25	0,25	0,25	0,25
γ	0,5	0,5	0,5	0,5	0,5
γ	0,75	0,75	0,75	0,75	0,75
γ	*1*	*1*	*1*	*1*	*1*
ϕ	0,25	0,25	0,25	0,25	0,25
ϕ	0,5	0,5	0,5	0,5	0,5
ϕ	0,75	0,75	0,75	0,75	0,75
ϕ	*1*	*1*	*1*	*1*	*1*
ϕ	1,25	1,25	1,25	1,25	1,25

Table 5.3: Other parameters and initial conditions

	Economy 1	Economy 2	Economy 3	Economy 4	Economy 5
μ_j	0.6	0.6	0.6	0.6	0.6
$\bar{z}_j$	0.001	0.001	0.001	0.001	0.001
$\iota_{i,j,c}$	0.4	0.4	0.4	0.4	0.4
$\rho_{i,j,c}$	0.2	0.2	0.2	0.2	0.2
$Y_{c,t-1}$	100	100	100	100	100
$Y_{w,t-1}$	401	401	401	401	401
$z_{j,t-1}$	0.25	0.25	0.25	0.25	
$w_{j,t-1}$	5	5	5	5	5
$A_{j,t-1}$	1	1	1	1	1
$z_{i,j,t-1}$	0.01	0.01	0.01	0.01	0.01
$A_{i,j,t-1}$	1	1	1	1	1
$a_{i,j,t-1}$	1	1	1	1	1
$K_{i,j,t-1}$	1	1	1	1	1

Chapter 6

Sectoral Specialisation and Growth Rate Differences

This chapter[1] follows the same theoretical frame then Chapter 5. We use the framework developed in this chapter to consider the possible relationship between patterns of sectoral specialisation and growth rate differences among economies.

Both empirical and theoretical literature on growth recently put forward the argument that sectoral specialisation can explain patterns in growth rate differences among economies. Dalum, Laursen and Verspagen (1999), Laursen (2000) and Meliciani (2001) present empirical evidences that specialisation affects growth. Specialisation patterns are linked to the competitiveness of the economies in the various sectors. They then affect growth rate differences due to the existence of differences in the growth potential of each sectors. Some models can be found in the literature trying to reproduce these facts : Among others, Verspagen (1993), Cimoli (1994), Dosi, Fabiani, Aversi and Meacci (1994) and Los and Verspagen (2003). Verspagen (1993), Cimoli (1994) and Los and Verspagen (2003) connect specialisation patterns to the existence of structural differences in productivity dynamics among sectors and economies. The effect of specialisation patterns on GDP growth rate differences derives from demand characteristics: income elasticity (Verspagen (1993) and Cimoli (1994)) or income elasticity plus the industrial input-output structure (Los and Verspagen (2003)). Dosi, Fabiani, Aversi and Meacci (1994), develop an evolutionary micro-founded multi-sectoral multi-country model. Authors conclude that these patterns of sectoral specialisation and GDP growth rate divergence generated by their model emerge from the interaction of micro-heterogeneity in behaviours and

[1]This chapter draws upon the model and simulation results presented in Lorentz (2004).

technological dynamics with the market selection mechanisms. Our model proposes an intermediate approach.

We develop a multi-sectoral growth model that links a Kaldorian macro-framework to an evolutionary modelling of technical change and industrial dynamics. In this sense we add a meso-level of analysis to the baseline model presented in Chapter 5

This chapter is organised as follows: The next section is devoted to the presentation of the model. Section 6.2 reports the main results emerging from simulations and their interpretations.

6.1 A Multi-Sectoral Growth Model.

This section presents a multi-sectoral extension to the growth model we proposed in the previous chapter. It considers economic growth as a demand-led process along Kaldorian lines. Economic growth is driven by external demand through a multiplier effect and technological change. These causal relationships are formally deduced from the balance of payment constraint.

Technical change emerges from the micro-dynamics following the evolutionary tradition. These replace the Kaldor-Verdoorn Law traditionally found in the Kaldorian literature.

Macro and micro-dynamics are strongly interrelated. Aggregate demand provides the necessary resources to finance firms' technological development and therefore their competitiveness. Selection among firms and among sectors is also rooted in macro-dynamics through demand and wage setting mechanisms. Hence the macro-evolution generates the resources of the firms and the mechanisms ensuring their redistribution among the latter. In this sense the macro-frame constraints the micro-dynamics.

On the other side micro-dynamics are the core of technological change, one of the engines of growth. The competitiveness of economies relies on national firms' ability to gain productivity.

These channels constitute the circular causality between macro and micro-dynamics, driving the entire long-run growth processes.

The structure of the model can be described as follows: We consider a set of C economies integrated in an economic system through trade relations. An economy $c \in [1; C]$, is referred to with the index c. When variables are indexed w, they concern the foreign economies with regard to the economy c.

Our system counts J sectors of activity. Each economy can produce and consume products of each of these sectors. A sector $j \in [1; J]$, is referred to using the index j.

For each economy, I firms are active in each of the J sectors. A firm $i \in [1; I]$, producing in sector j and based in the economy c is referred to with the indexes i, j, c.

The entire economic system then counts C economies, J sectors, and $C * J * I$ firms. The index t refers to the time step.

6.1.1 The macro-economic framework: International trade, economic growth, and wage dynamics.

This subsection presents the macro-economic framework of the model. The latter is decomposed in two distinct processes. First we consider GDP dynamics as deduced from the balance of payment constraint. Second, we define wage dynamics as correlated to labour productivity dynamics.

We assume that the considered economies are part of an integrated monetary system. We then excluded monetary adjustment to possible trade disequilibria. This is the case if considering as unit of analysis regions or countries in a single currency area. Economies being subject to balance of payment constraint, it thus implies that imports equal exports. Given the functional representation of imports and exports, as developed below, we can then deduce the GDP dynamics from the balance of payment constraint.

The macro-economic framework we developed here is directly rooted in the formal interpretations of Kaldor's cumulative causation approach of the economic growth process. Our formal representation found its inspiration in this respect in Thirlwall (1979) model, or in the more recent multi-sectoral models by Cimoli (1994) or Verspagen (1993), among others.

Balance of payment constraint and the determination of aggregate demand:

For each sector j of an economy c, exports are defined as follows:

$$X_{j,c,t} = s_{j,w,t}(Y_{w,t})^{\alpha_c} z_{j,c,t} \tag{6.1}$$

where $Y_{w,t}$ represents the GDP of the rest of the world, computed as the sum of GDP levels of all foreign economies, $z_{j,c,t}$ represents the market share of the economy on the international markets for the sector j. α_c is the income elasticity of the rest of the world with respect to economy c exports. $s_{j,w,t}$ represents the share of income devoted to the consumption of sector j products by the rest of the world. It is formally computed as follows:

$$s_{j,w,t} = \frac{Y_{w,t}^{\varepsilon_j}}{Y_{w,t}}$$

Where ε_j represents the income elasticity of sector j products' consumption.

The market share of the economy in a sector is a proxy for the price competitiveness of the economy in the sector. It is given by the sum of the market shares of the domestic firms active in this sector:

$$z_{j,c,t} = \sum_i z_{i,j,c,t}$$

Each firm's market shares is defined through a replicator dynamic, function of firm's relative competitiveness. Hence the market share of each firm will be computed as follows:

$$z_{i,j,c,t} = z_{i,j,c,t-1} \left(1 + \phi \left(\frac{E_{i,j,c,t}}{\bar{E}_{j,t}} - 1 \right) \right) \tag{6.2}$$

where $z_{i,j,c,t}$ represents the market share of firm i, $p_{i,j,c,t}$ the price of its product. $E_{i,j,c,t}$ stands for firm i, in sector j level of competitiveness:

$$E_{i,j,c,t} = \frac{1}{p_{i,j,c,t}}$$

$\bar{E}_{j,t}$, the average competitiveness on the international market, is computed as follows:

$$\bar{E}_{j,t} = \sum_{c,i} z_{i,j,c,t-1} E_{i,j,c,t}$$

The parameter ϕ measures the reactivity of the selection mechanism to competitiveness. Given our specification this parameter can be interpreted as a measure of price elasticity.

Imports follow the exports' specification scheme. They are function of domestic economy income, of domestic share of consumption of sector j goods, and of the rest of the world's market share. Formally imports are computed as follows:

$$M_{j,c,t} = s_{j,c,t} (Y_{c,t})^{\beta_c} (1 - z_{j,c,t}) \tag{6.3}$$

With

$$s_{j,c,t} = \frac{Y_{c,t}^{\varepsilon_j}}{Y_{c,t}}$$

$s_{j,c,t}$ represents the share of income devoted to the consumption of the products of sector j sector. Note that ε_j, the income elasticity of consumption of sector j products is fixed and equal across economies. The parameter β_c represents the income elasticity to import. $Y_{c,t}$ represents aggregate demand which, given the demand-led nature of the model, also defines GDP.

The growth rate of exports and imports for each sector can be deduced from these expressions as :

$$\frac{\Delta X_{j,c,t}}{X_{j,c,t-1}} = (\alpha_c + \varepsilon_j - 1)\frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \phi\left(\frac{E_{j,c,t}}{\bar{E}_{j,t}} - 1\right) \tag{6.4}$$

$$\frac{\Delta M_{j,c,t}}{M_{j,c,t-1}} = (\beta_c + \varepsilon_j - 1)\frac{\Delta Y_{c,t}}{Y_{c,t-1}} - b_{j,c,t-1}\phi\left(\frac{E_{j,c,t}}{\bar{E}_{j,t}} - 1\right) \tag{6.5}$$

with

$$b_{j,c,t-1} = \frac{z_{j,c,t-1}}{1 - z_{j,c,t-1}}$$

External trades are subject to balance of payment constraint. Hence the growth rate of exports has to equal growth rate of imports. Thus:

$$\frac{\Delta X_{c,t}}{X_{c,t-1}} = \frac{\Delta M_{c,t}}{M_{c,t-1}} \tag{6.6}$$

With

$$X_{c,t} = \sum_j p_{j,c,t} X_{j,c,t} \text{ and } M_{c,t} = \sum_j p^m_{j,c,t} M_{j,c,t}$$

$$p_{j,c,t} = \sum_i p_{i,j,c,t}\frac{z_{i,j,c,t}}{z_{j,c,t}} \text{ and } p^m_{j,c,t} = \sum_{\bar{c}\neq c}\sum_i p_{i,j,\bar{c},t}\frac{z_{i,j,\bar{c},t}}{1 - z_{j,c,t}}$$

The balance of payment constraint can be rewritten as follows:

$$\sum_j i_{j,c,t-1}\frac{\Delta M_{j,c,t}}{M_{j,c,t-1}} + \sum_j i_{j,c,t-1}\frac{\Delta p^m_{j,c,t}}{p^m_{j,c,t-1}} = \sum_j e_{j,c,t-1}\frac{\Delta X_{j,c,t}}{X_{j,c,t-1}} + \sum_j e_{j,c,t-1}\frac{\Delta p_{j,c,t}}{p_{j,c,t-1}} \tag{6.7}$$

where:

$$i_{j,c,t-1} = \frac{p^m_{j,c,t-1} s_{j,c,t-1}(1 - z_{j,c,t-1})}{\sum_j p^m_{j,c,t-1} s_{j,c,t-1}(1 - z_{j,c,t-1})} \text{ and } e_{j,c,t-1} = \frac{p_{j,c,t-1} s_{w,j,t-1} z_{j,c,t-1}}{\sum_j p_{j,c,t-1} s_{w,j,t-1} z_{j,c,t-1}}$$

$i_{j,c,t-1}$ and $e_{j,c,t-1}$ weigh the importance of each sector' s dynamics in gross imports and exports dynamics. These two components reflect the sectoral structure of the economy. Their changes through time illustrate the structural changes in the economies.

The introduction of the balance of payment constraint allows us to express the GDP growth rate as function of the rest of the world GDP growth rate and of market share growth rate. Formally GDP growth rate will be computed as follows:

$$\frac{\Delta Y_{c,t}}{Y_{c,t-1}} = \gamma_{c,t-1}\frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \lambda_{c,t-1}\phi\left[\sum_j \theta_{j,c,t-1}\left(\frac{E_{j,c,t}}{\bar{E}_{j,t}} - 1\right)\right] + \lambda_{c,t-1}\sum_j \kappa_{j,c,t-1} \tag{6.8}$$

With

$$\gamma_{c,t-1} = \frac{\alpha_c + \sum_j e_{j,c,t-1}\varepsilon_j - 1}{\beta + \sum_j i_{j,c,t-1}\varepsilon_j - 1} \tag{6.9}$$

$$\lambda_{c,t-1} = \frac{1}{\beta + \sum_j i_{j,c,t-1}\varepsilon_j - 1} \tag{6.10}$$

$$\theta_{j,c,t-1} = e_{j,c,t-1} + i_{j,c,t-1}b_{j,c,t-1} \tag{6.11}$$

$$\kappa_{j,c,t-1} = e_{j,c,t-1}\frac{\Delta p_{j,c,t}}{p_{j,c,t-1}} - i_{j,c,t-1}\frac{\Delta p^m_{j,c,t}}{p^m_{j,c,t-1}} \tag{6.12}$$

The first component of the right hand side of the equation captures a trade multiplier like effect on GDP growth rates. The second and third components mirror the effects of technological change on GDP dynamics through respectively the linkage between sectoral competitiveness and GDP growth, and between price changes and GDP growth. This representation allows a clear decomposition between the effect of external demand and of technological change on the 'short-run' GDP dynamics. The relative weight of these components is strongly linked to the structural characteristics of the economy. These characteristics are themselves subject to changes along time, due to the evolution of demand and technological change, leading to more complex interactions in defining the long-run growth patterns than in this short-run specification.

Wage determination:

Wages are set at the sectoral level. For a given sector j wage dynamics will be correlated to sector j productivity growth rate ($\frac{\Delta A_{j,c,t}}{A_{j,c,t-1}}$) and to the entire economy productivity growth rate ($\frac{\Delta A_{c,t}}{A_{c,t-1}}$). The effect of these two variables on wage dynamics is weighted by the parameter $\nu \in [0; 1]$, such that :

- When $\nu = 1$, the wage dynamics for every sector only depend on the macro-level productivity growth rate. (i.e. as a centralised wage negotiation system)

- When $\nu = 0$, the wage dynamics for every sector only depend on the sector-level productivity growth rate. (i.e. as a sectoral wage negotiation system)

Wage dynamics of the sector j, in the economy c is represented as follows:

$$\frac{\Delta w_{j,c,t}}{w_{j,c,t-1}} = \nu \frac{\Delta A_{c,t}}{A_{c,t-1}} + (1-\nu)\frac{\Delta A_{j,c,t}}{A_{j,c,t-1}} \tag{6.13}$$

With

$$A_{c,t} = \frac{Y_{c,t}}{L_{c,t}} \text{ and } A_{j,c,t} = \frac{Y_{j,c,t}}{L_{j,c,t}}$$

Note that the wage level defined with this process during the period t is applied by firms at period $t+1$. Wage dynamics in our model act as a second macro-constraint on firms. Hence, it affects directly firms competitiveness and then the effect of the selection mechanisms on firms. Firms in a given sector of an economy will loose competitiveness if their own productivity growth rate is slower then the average one. Moreover, when $\nu \neq 0$, wage dynamics generate a selection process among sectors. Hence, if the average productivity of a sector grows slower then the average productivity growth rate of the entire economy, through wage dynamics, this sector looses competitiveness. The amplitude of this effect directly depends on the value of the parameter ν. As argued in the last section of this paper wage dynamics through the process described above play a major role in the specialisation dynamics.

6.1.2 Firms: production, construction of production capacity

This subsection is devoted to the description of the microeconomic level of the model. We consider here the formal representation of firms' production capacities, investment decisions and R&D activity. Note that the representation provided is common to all sectors and economies. Sectoral or economy-wide specificity, when considered, takes the form of specific parameter values. Formally the micro-level of this model is similar to the one found in the previous chapter. Hence, following the evolutionary tradition we consider a population of bounded rational firms that can differ in their technological characteristics and behaviours. Technical change emerges at the firm level as a mutation process. More precisely technical change is embodied in capital vintages developed by firms to build and improve their production capacities.

Firms then play two specific role in the model. First they satisfy the demand needs. This provides them with the necessary resources to sustain the development of their production capacities. Second, through this process they generate technical change. The latter then affects the macro-dynamics, increasing the economy competitiveness and therefore affects demand dynamics.

Production and pricing:

Firms' production process is represented by a Leontiev production function with labour as unique production factor. Capital goods enter the production function in defining labour productivity. The production function is represented as follows :

$$Y_{i,j,c,t} = A_{i,j,c,t-1} L^{p}_{i,j,c,t} \tag{6.14}$$

where $Y_{i,j,c,t}$ is the output of firm i, producing in sector j at time t. $A_{i,j,c,t-1}$ represents labour productivity and $L^{p}_{i,j,c,t}$ the labour force employed in the production process. Output is constrained by the demand directed to the firms and defined at the macro-economic level. The level of production of each firm is computed as a share of sector j demand[2] given by their relative market share such as:

$$Y_{i,j,c,t} = \frac{z_{i,j,c,t}}{z_{j,c,t}} Y_{j,c,t}$$

Labour productivity is function of the firms' accumulation of capital goods. Each capital good embodies a level of labour productivity. Investment in the different vintages of capital goods modifies the labour productivity of the firm. Hence, at the end of any period t, we define the level of labour productivity as follows:

$$A_{i,j,c,t} = \frac{I_{i,j,c,t} a_{i,j,c,t-1}}{\sum_{\tau=1}^{t} I_{i,j,c,\tau}} + \frac{\sum_{\tau=1}^{t-1} I_{i,j,c,\tau}}{\sum_{\tau=1}^{t} I_{i,j,c,\tau}} A_{i,j,c,t-1} \tag{6.15}$$

where $a_{i,j,c,t-1}$ represent the labour productivity embodied in the capital good developed by the firm i during the period $t-1$. $I_{i,j,c,t}$ represents the level of investment in capital goods of the firm.

Firms set prices through a mark-up process. This mark-up is applied to unitary production costs, corresponding here to labour costs. Prices are computed as follows:

$$p_{i,j,c,t} = (1 + \mu_j) \frac{w_{c,t-1}}{A_{i,j,c,t-1}} \tag{6.16}$$

where $p_{i,j,c,t}$ represents the price set by firm i at time t, μ_j the mark-up coefficient and $w_{j,t-1}$ the wage level set at the macro level for the entire sector. Note that we assume here that the mark-up coefficients are fixed for each firm in a given sector of a given economy.

[2] Sector j demand is computed as: $Y_{j,c,t} = X_{j,c,t} + s_{j,c,t}(1 - (Y_{c,t})^{\beta_c - 1}) Y_{c,t} z_{j,c,t}$.

Firm's profit level will then be computed as follows:

$$\Pi_{i,j,c,t} = p_{i,j,c,t} Y_{i,j,c,t} - w_{j,c,t-1} L^{p}_{i,j,t} = \mu_j \frac{w_{j,c,t-1}}{A_{i,j,c,t-1}} Y_{i,j,c,t} \tag{6.17}$$

Profits constitute in the model the only financial resource for firms' investments.

Building production capacities:

As introduced previously, to build but also improve their production capacities, firms have to accumulate capital vintages. Each capital good is developed in-house by firms and then introduced in their production technologies. This process is decomposed in two phases. First firms explore and develop new capital goods, through local search or through the adaptation of existing capital goods to their own production techniques. This phase takes place within the R&D activity of the firms. The latter is financed by investments in R&D. The second stage consists in introducing the outcome of the R&D activity within the production process. This stage is costly and requires firms to invest in the exploitation of the latest capital good vintage. The level of investment determines the relative importance of the latest capital goods in the production process and therefore determines the effective productivity gains, as described above. These two distinct investments are subject to the firms financial constraint. Firms' only resources for investments are their profits. More profitable firms are more inclined to invest and therefore to improve their production capacities and their competitiveness.

The investment decision timing is set as follows, first firms invest in capital goods, in order to gain from the already developed vintages, and then invest in R&D. Investment in capital goods corresponds to a share $\iota_{i,j,c}$ of firms' sales. Given the financial constraint the investment level in capital good is formally represented as follows:

$$I_{i,j,c,t} = min \left\{ \iota_{i,j,c} Y_{i,j,c,t} \ ; \ \Pi_{i,j,c,t} \right\} \tag{6.18}$$

Investments in R&D are a share $\rho_{i,j,c}$ of their sales. R&D investment will correspond to the hiring of workers assigned to the research activity :

$$R_{i,j,c,t} = \frac{1}{w_{j,c,t-1}} \min\{\rho_{i,j,c} Y_{i,j,c,t}; \Pi_{i,j,c,t} - I_{i,j,c,t}\} \tag{6.19}$$

The formal representation of the R&D process is explicitly inspired by evolutionary modelling of technical change. Hence following Nelson and Winter (1982) we will consider that the probability of success of research is an increasing function of R&D investments. Formally the R&D activity is represented by the following algorithm:

1. Firms draw a number from a Uniform distribution on [0 ; 1].
2. If this number is contained in the interval $[0\ ;\ \frac{R_{i,j,c,t}}{Y_{i,j,c,t}}]$, the R&D is successful. Hence a new capital good vintage has been developed.
3. If R&D is successful, its outcome is drawn from the following distribution. We differentiate here explicitly innovative firms from imitative ones:

$$a_{i,j,c,t} = \max\{a_{i,j,c,t-1} + \epsilon_{i,j,c,t}; a_{i,j,c,t-1}\} \tag{6.20}$$

$$\epsilon_{i,j,c,t} \sim N(0; \sigma_{i,j,c,t}) \tag{6.21}$$

$$\text{with } \begin{cases} \sigma_{i,j,c,t} = \sigma_{j,c} & \text{if the firm is an innovator} \\ \sigma_{i,j,c,t} = \chi_{j,c}(\bar{a}_{j,t} - a_{i,j,c,t}) & \text{if the firm is an imitator} \end{cases} \tag{6.22}$$

The outcome of the R&D process defines the labour productivity level embodied in the newly discovered capital vintage ($a_{i,j,c,t}$). $\bar{a}_{j,t}$ represents the average productivity level embodied in the latest capital vintages developed by firms. It is formally computed as:

$$\bar{a}_{j,t} = \sum_{i,c} z_{i,j,c,t} a_{i,j,c,t-1}$$

Hence $\bar{a}_{j,t} - a_{i,j,c,t}$ represents firm i, j, c technological gap, while the parameter $\chi_{j,c} \in [0; 1]$ can be seen as the degree of access to spillover for the imitating firms.

Firms exit the market if their market share is lower then $\bar{z}_j$. They are replaced by firms with a productivity level and value of the latest capital vintage developed equal to the average values of these variables within the sector and economy of the exiting firms and a market share equal to $\bar{z}_j$. In this respect the number of firms remains constant. An exiting innovator is replaced by an entrant innovator, and an exiting imitator by an entrant imitator. The proportion of innovators, and thus imitators, then remains constant.

6.2 Sectoral Specialisation and Growth Rate Differences: Main Simulation Results

The model, as detailed in the previous section, is developed to consider the determinants of sectoral specialisation and their effect on growth rate differences among the integrated economies. We do not assume here any ad-hoc specialisation. We rather look for specialisation to emerge from the dynamics generated through the model.

Some models can be found in the literature that raise the question of the emergence of specialisation patterns. Due to some similarities on the theoretical ground, one might particularly think about Verspagen (1993), Aversi, Dosi, Fabiani and Meacci (1994), Cimoli (1994) or Los and Verspagen (2003) among others. Verspagen (1993), Cimoli (1994) and Los and Verspagen (2003) connect specialisation patterns to the structural differences among economies in the sources of technical change and productivity gain. They base their analysis on the Kaldor-Verdoorn Law. These models then link specialisation patterns to GDP growth rate differences through the differences in income elasticity of sectors' demand. In this respect these models are close to the Kaldorian analysis of growth rate differences. Dosi, Fabiani, Aversi and Meacci (1994), develop an evolutionary micro-founded multi-sectoral growth model. They show the emergence of significant patterns of GDP growth rate divergence among economies. These can be coupled to sectoral specialisation patterns in some economies. Authors conclude that these patterns emerge from the interaction of micro-heterogeneity in behaviours and technological dynamics with the market selection mechanisms. They thus consider these patterns as micro-driven.

We consider here economies initially identical, endowed with the same potentials of productivity growth, and equal access to spillovers. Technological heterogeneity among firms and therefore economies in our model results from the stochastic generation of technical change at the micro-level.

As for most of the models incorporating evolutionary features, we need to resort to numerical simulations.[3] Simulations are set through the following scheme. Our artificial system counts 4 economies and 5 industrial sectors. Each economy is producing and consuming the output of each of these sectors and counts 20 active firms per sectors. An economy is then composed of 100 firms, and each sector counts 80 firms competing against each others. In each sector, and each country half of the firms are set being innovators

[3]Simulations are implemented using the Laboratory for Simulation Development (LSD) environment. See Valente and Andersen (2002)

and therefore half of them are imitators. Exiting innovators are replaced by entering innovators, so that this proportion remains constant. All firms and all economies are initially similar, in terms of initial conditions and parameter settings.These settings are detailed in Tables 6.2, 6.3 and **??**.

Our analysis focuses on the effect of two groups of parameters. A first one concerns macro-components of the model, while the second considers technological parameters. The macro-level parameters are the following:

- ν, the parameter weighting the effect of sector versus aggregate productivity growth rates in the sector-level wage dynamics. This parameter generates a selection among sectors, favouring the most dynamic ones in terms of productivity increases, through the relationship between wage and prices and therefore competitiveness.

- ϕ, the price elasticity, included in the replicator equation, directly influences the speed of the selection process among firms in a given sector. This parameter should somehow regulate the amplitude of the specialisation process.

- ε_j, for which we consider the effect of growing inter-sector heterogeneity. Income elasticity differences are usually considered in the literature as a source of GDP growth rate differences when specialisation occurs. Economies specialising in higher elasticity sectors (i.e. with a high demand potential) should grow faster.

The set of technological parameters is the following:

- $\sigma_{j,c}$ is a parameter of the stochastic process defining the outcome of a successful R&D activity for innovators. It can be interpreted as the range of technological opportunities. We consider here the effect of a growing heterogeneity of technological opportunities among sectors. By doing this we impose some structural differences among sectors in their potential of productivity gains.

- $\chi_{j,c}$ defines the appropriability of technological spillovers. It influences imitators ability to access and adopt more advanced technologies, and then reduce their technological gap. A greater appropriability of spillovers should therefore limit productivity differences among economies in a given sector.

The next subsections are devoted to the description and the interpretation of some of the simulation results. For each parameter configurations, the results presented reflect the average value of the considered variables over 20 simulations. Each simulation lasts 500 steps.

6.2.1 Some patterns of sectoral specialisation and their determinants

Our first concern is to investigate the factors influencing specialisation patterns emerging from the dynamics generated by the model. Note that specialisation has to be understood here as concentration of production in a limited number of sectors. As we see later, in this sense we look for specialisation as understood traditionally in international trade theories, namely the allocation or repartition of the production of various sectors among the different economies of the system. We also consider specialisation at the economy level, that is not directly linked to international trade, but rather defined the sectoral structure of an economy. As we see later these two variant of the specialisation process are generated by two separate mechanisms.

The level of specialisation is measured through the the inverse Herfindahl index of sectors' production shares. Note that we do not differentiate between the share of production for the foreign and the domestic markets. We compute this index as follows:

$$H_{c,t} = \left[\sum_{j=1}^{5} \left(\frac{p_{j,c,t} Y_{j,c,t}}{\sum_{j=1}^{5} p_{j,c,t} Y_{j,c,t}} \right)^2 \right]^{-1}$$

This index estimates the number of sectors in which production is concentrated. Given the specification of our model, this indicator is defined in the interval $[1;5]$. When $H_{c,t}$ equals 5, the economy c produces the same level of output along the 5 sectors. In other words, the economy do not specialise its production in a specific sector. When $H_{c,t}$ equals 1, the production of the economy c is concentrated in a specific sector. It is then highly specialised.

Our analysis of specialisation concentrates on the average specialisation level among the 4 economies composing the system. We refer along this section to $\bar{H}_t$ that is computed as follows:

$$\bar{H}_t = \frac{1}{4} \sum_{c=1}^{4} H_{c,t}$$

Figures 6.1, 6.5, 6.7 and 6.10 report the average specialisation level $\bar{H}_t$ after 500 simulation steps for a selected set of parameter settings. The parameter configurations considered here aim to underline the importance of the macro-frame on the economy dynamics by catalysing, amplifying or absorbing the effects of the technological micro-dynamics. We therefore choose to confront settings of the parameter ν, controlling for inter-sector selection mechanisms to increases in price elasticity ϕ (Figure 6.1), increases in heterogeneity in income elasticity (Figure 6.5), increases in technological opportunity (σ_j) heterogeneity (Figure 6.7) and increases in the absorptivity of spillovers (χ) (Figure 6.10).

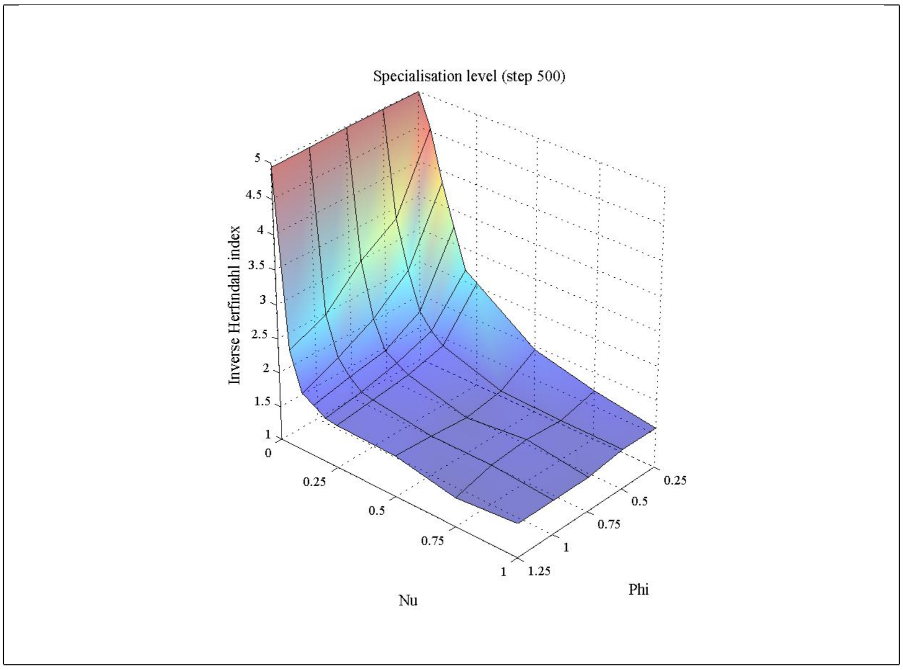

Figure 6.1: Specialisation levels and selection parameters (ϕ vs. ν)

Result 12 *Increasing the amplitude of the selection mechanisms intra (ϕ) and inter(ν)-sectors increases the level of specialisation. This result is linked to the tendency of the stochastic process to generate uneven technical change among firms and sectors, combined with the cumulative nature of productivity gains. In this case, the specialisation process is closed to the one found in the traditional trade literature.*

The results presented in Figure 6.1 confirm our intuition on the role of catalyser played by the wage setting mechanisms. Hence, whatever the parametrisation, as long as $\nu \neq 0$, not only specialisation occurs but its level increases (i.e. $\bar{H}_t$ decreases), as ν increases (see Figure 6.1 and 6.2).

These results are directly linked to the cumulative nature of productivity gains (through investments in capital goods) combined with the stochastic nature of technical change generates and reinforces productivity gaps among firms and then potentially among sectors. Hence as presented in Figure 6.3, the model generates significant differences in productivity growth rates among sectors, even if initially equal. With $\nu > 0$, through wage dynamics and its effect on competitiveness, it magnifies the heterogeneity among sectors. These productivity gaps among firms and sectors then undeniably lead to sectoral specialisation.

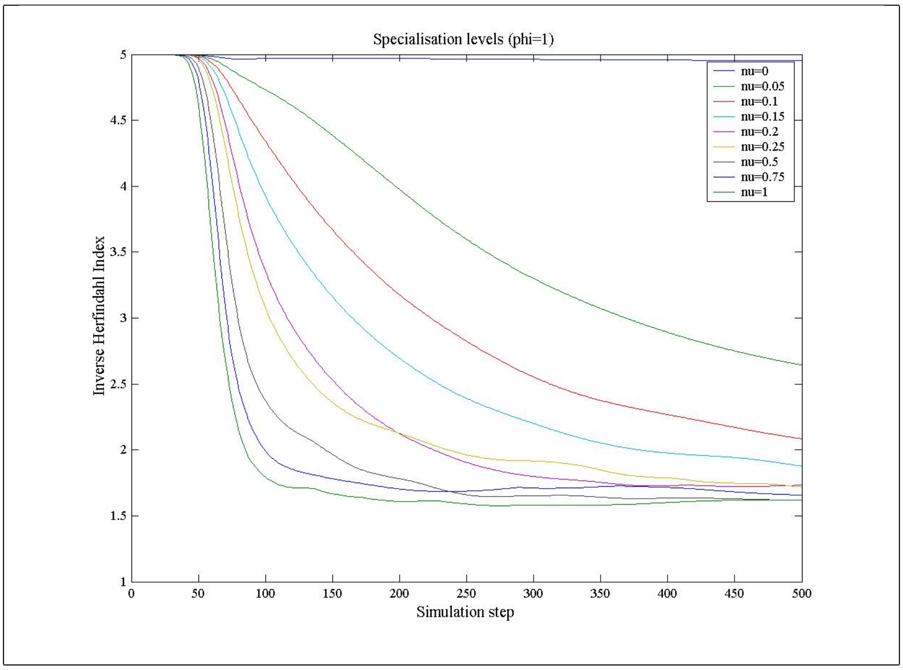

Figure 6.2: Specialisation dynamics with various values of ν

These differences are amplified when the inter-sector selection mechanisms are active and increased (Figure 6.2) when increasing ν. In other words by fostering selection between sectors, wage dynamics influences directly the productivity dynamics, fostering specialisation. Specialisation is therefore itself a cumulative and self-reinforcing process.

Hence For small values of ν, these mechanisms are significantly amplified by increases in price elasticity (ϕ), as depicted in Figure 6.1 and 6.4.

A second significant specialisation pattern is to be found when increasing differences in income elasticity among sectors, as shown by Figure 6.5. Heterogeneity in income elasticity leads to sectoral specialisation. In this case, specialisation is not only driven by technological dynamics but also by the structure of aggregate demand and it evolution.

Result 13 *Increasing differences in income elasticity among sectors significantly affects specialisation, even when $\nu = 0$. The level of heterogeneity in income elasticity seems to affect the range of speed of specialisation.*

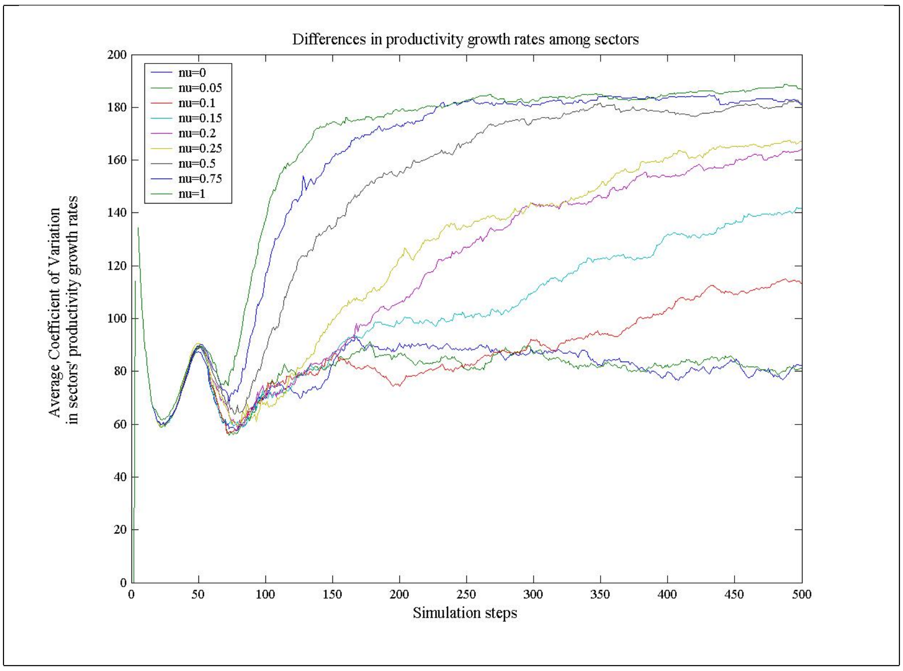

Figure 6.3: Inter-sector differences in productivity growth rates and inter-sector selection through wages

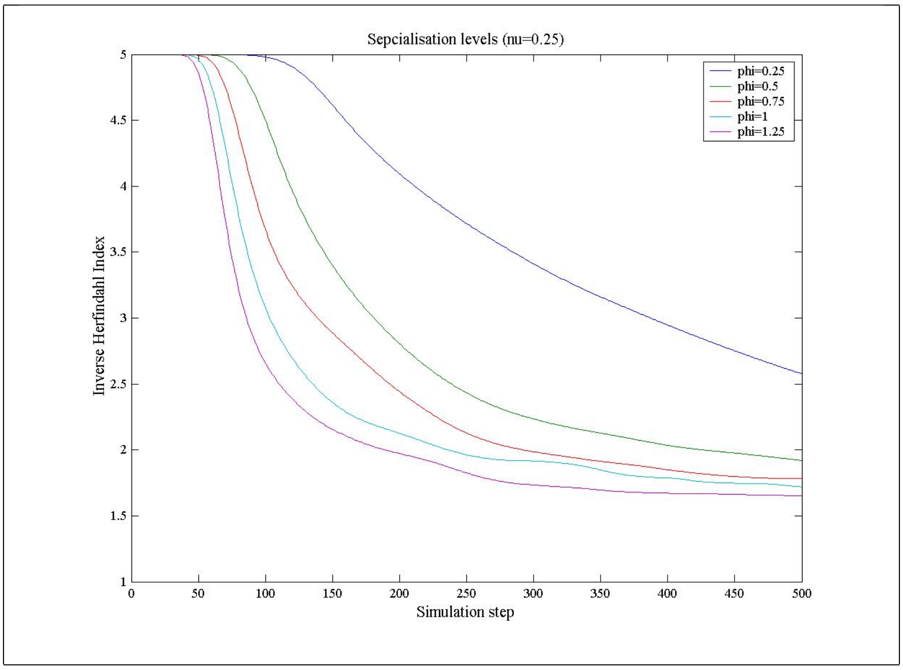

Figure 6.4: Specialisation dynamics and price elasticity (ϕ)

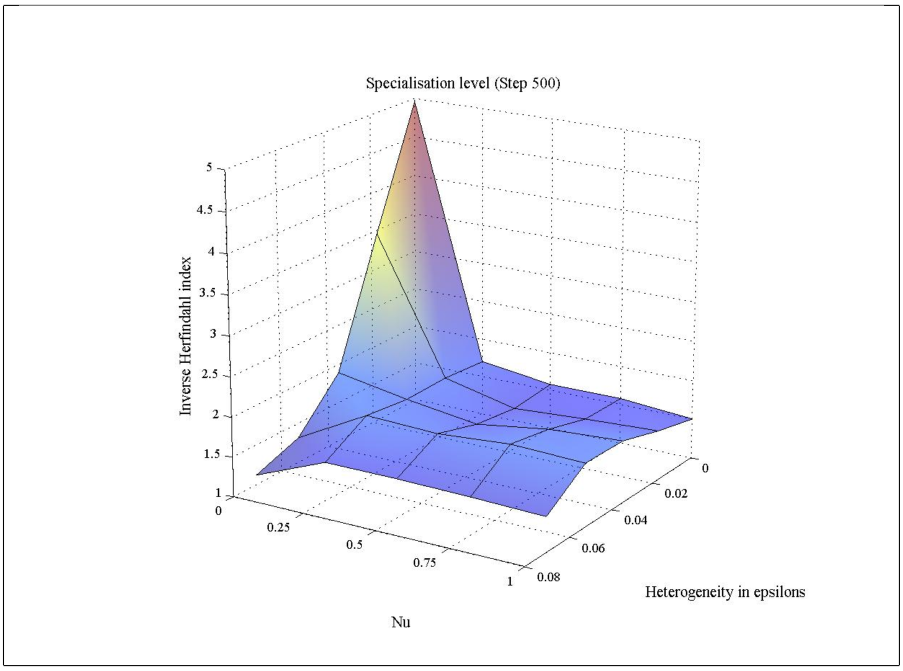

Figure 6.5: Specialisation levels with heterogeneous income elasticities ($StdDev(\varepsilon_j)$ vs. ν)

Hence, even for $\nu = 0$ (Figure 6.6), growing the heterogeneity in ε_j generates patterns of concentration of production in a limited number of sectors. The specialisation level grows with the heterogeneity. The mechanisms described in the previous case (when growing ν) are here neutralised. Specialisation is therefore deterministically led by demand. Moreover, as depicted in the first picture in Figure 6.5 and 6.6, differences in income elasticity seem to affect significantly both the speed and the range of sectoral specialisation.

This process seems however to disappear for high values of ν (Figure 6.5). For low values of ν, the demand effect dominates the effect linked to technical change. It seems however to gradually disappear while increasing ν as shown by Figure 6.5. The mechanisms linked to the selection mechanisms then dominates.

The next two parameters considered concern the micro-level technological characteristics. More precisely we investigate here the effect of increasing differences in technological opportunities (σ_j) among sectors (Figure 6.7) and of growing the appropriability of technological spillovers (χ_j) (Figure 6.10).

Result 14 *Increasing the heterogeneity in technological opportunities relatively decrease the level of specialisation. This configuration implies a con-*

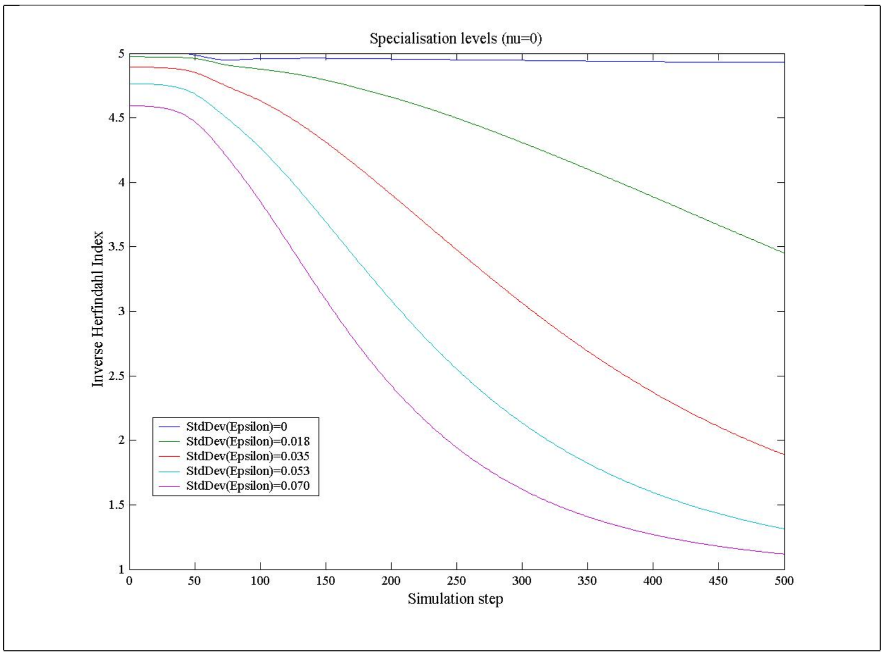

Figure 6.6: Specialisation dynamics and heterogeneity in income elasticity

centration of production in the most favoured sector and a secondary specialisation process among the remaining sectors. This pattern is related to the homogeneous setting of income elasticities. It disappears and even revers when increasing the differences in income elasticity.

These parameters influence directly the processes generating technical change. If the effect led by ν is directly linked to the fact that technical change can unevenly occurs among firms and sectors, it is therefore highly expected that these parameters also influence specialisation patterns: First, the changes in σ_j might therefore reinforce productivity gaps among sectors by providing significantly different technological opportunities. Figure 6.7 seems nevertheless to contradict this intuition. Hence for any $\nu \neq 0$, when the differences in technological opportunities grows, the specialisation level decreases. For the highest level of heterogeneity, $\bar{H}_{t=500}$ take values around 2. On average, along the 4 economies, production is therefore concentrated in 2 sectors. This result might be explained as follows: With high differences in technological opportunities, economies concentrate their production in the most dynamic sector. The remaining 4 sectors require demand to be satisfied[4]. Economies might therefore specialise in a second sector of activity.

[4]Note that this result occurs only when sectors are characterised by equal income elasticities.

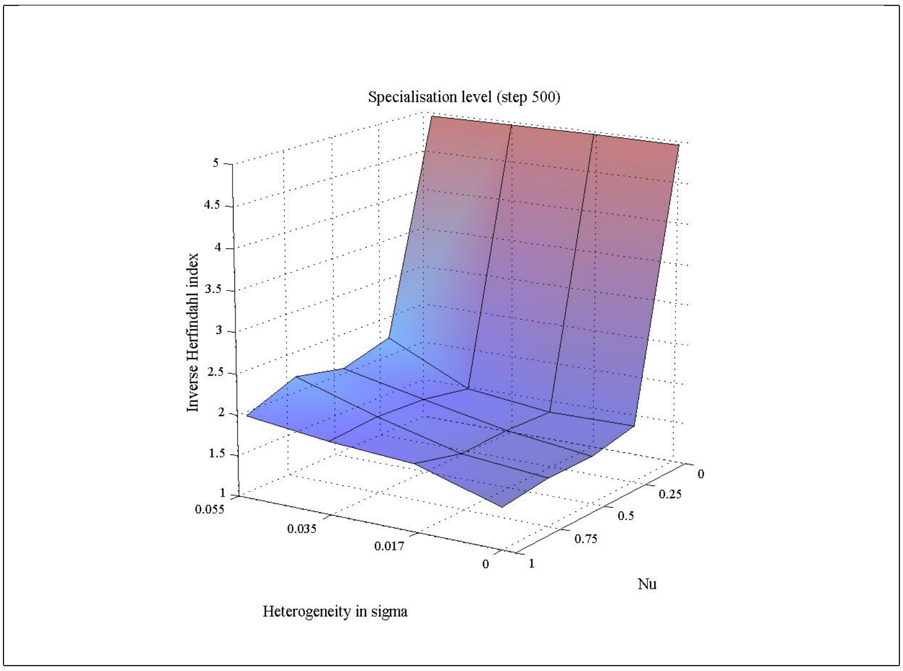

Figure 6.7: Specialisation levels with heterogenous σ_j vs. ν

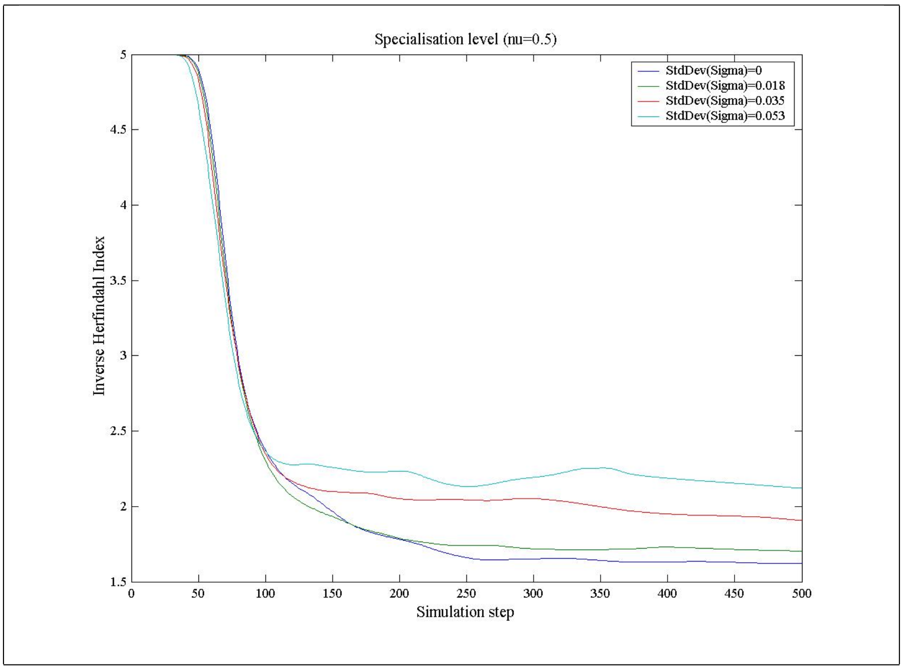

Figure 6.8: Specialisation dynamics and heterogeneity in σ_j

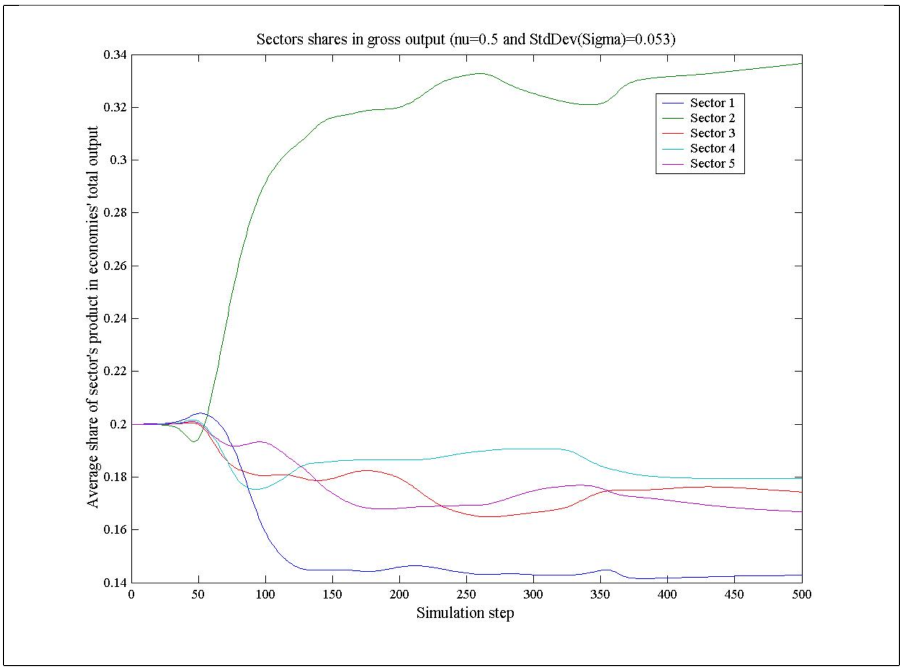

Figure 6.9: Sectors' share in total production (Average over the 5 economies)

This possible explanation is sustained by the results presented in Figure 6.9. When considering highly heterogeneous technological opportunities between sectors, the production tends to concentrate on average on the most favoured sector, while the rest of the production is distributed among the remaining ones. This process might then take place due to productivity gaps among the remaining sectors. In other words, with high heterogeneity in technological opportunities we might observe a second order specialisation process.

Second, increasing χ_j is supposed to reduce technological gaps among firms in the same sector. Therefore, if productivity gaps emerge among economies, the latter should tend to reduce through imitation with high values of χ_j. Imitation should not affect productivity differences among sectors. Growing χ should therefore contribute to maintain or even increase differences among sectors and thus affect specialisation. As depicted by Figure 6.10, increasing the value of χ_j does not significantly affect specialisation.

To briefly summarise the results detailed in this section, one might note the predominance of two main specialisation regimes :

- Uneven technical change among firms and sectors, reinforced by the cumulative nature of productivity gains is one of the major forces driving specialisation. It however requires some diffusion channels across sectors. This role is played by wage dynamics. Moreover, this might

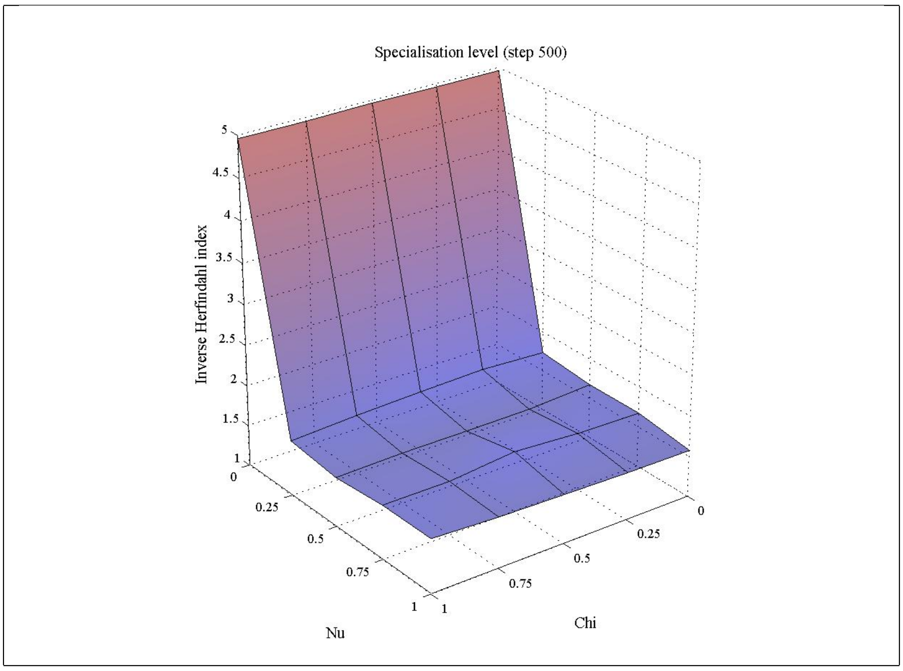

Figure 6.10: Specialisation levels and the appropriability of spillovers (χ)

predominate over all the other mechanisms.

- The sectoral concentration of production can also be demand-led. This effect is directly linked to the demand-driven nature of our model. Demand constrains production. Therefore economies might natural concentrate their production toward sectors with the highest income elasticity.

These two regimes are complementary in explaining the emergence of specialisation patterns. Hence specialisation can be driven by technology, by demand or the both. In any case the macro-frame plays a determinant role, first in catalysing technology dynamics and diffusing them at the macro-level, and second the macro-structure of demand can have a direct influence on the specialisation patterns.

6.2.2 Sectoral specialisation and GDP growth rate differences

Our principal concern when considering patterns of specialisation is their possible connection with patterns of GDP growth rate differences. This subsection proposes to present and interpret the outcome of simulations in terms of growth rate differences. We resort to the same parameter settings as for specialisation. These differences are measured through the coefficient of variation in GDP growth rates among the 4 economies over 500 simulation steps. We recall that the coefficient of variation is defined as the ratio between standard deviation and absolute average. This indicator provides a measure of relative variability.

Figures 6.11, 6.13, 6.15 and 6.16 present the average coefficient of variation in GDP growth rates among economies along the 500 simulation steps for the various parameter configuration, and Figures 6.12 and 6.14 report the dynamics of this indicator along the 500 simulation steps for some parameter specifications. A first look at the results tends to sustain the idea that specialisation patterns and growth rate differences patterns are connected. Hence parameter settings leading to significant specialisation patterns also lead to increases in the GDP growth rate differences among economies.

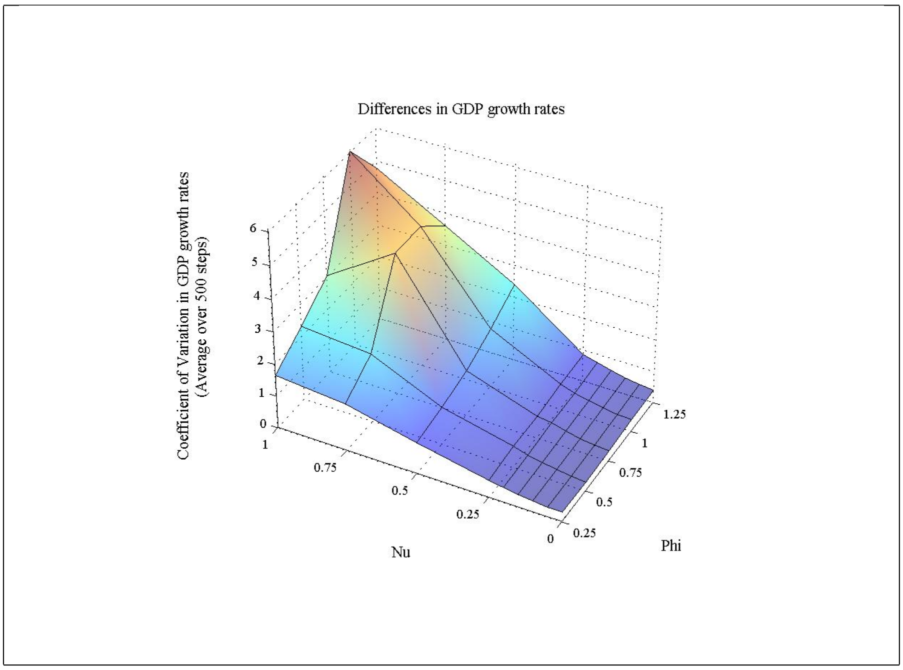

Figure 6.11: Differences in GDP growth rates (Average over 500 steps) and selection parameters (ϕ vs. ν)

Result 15 *Increasing the value of ν relatively increases the differences in GDP growth rates. But these differences are only transitory.*

Figure 6.11 depicts the effect of increasing selection parameters: ϕ and ν. As for specialisation, increasing ν for given values of ϕ generates growing

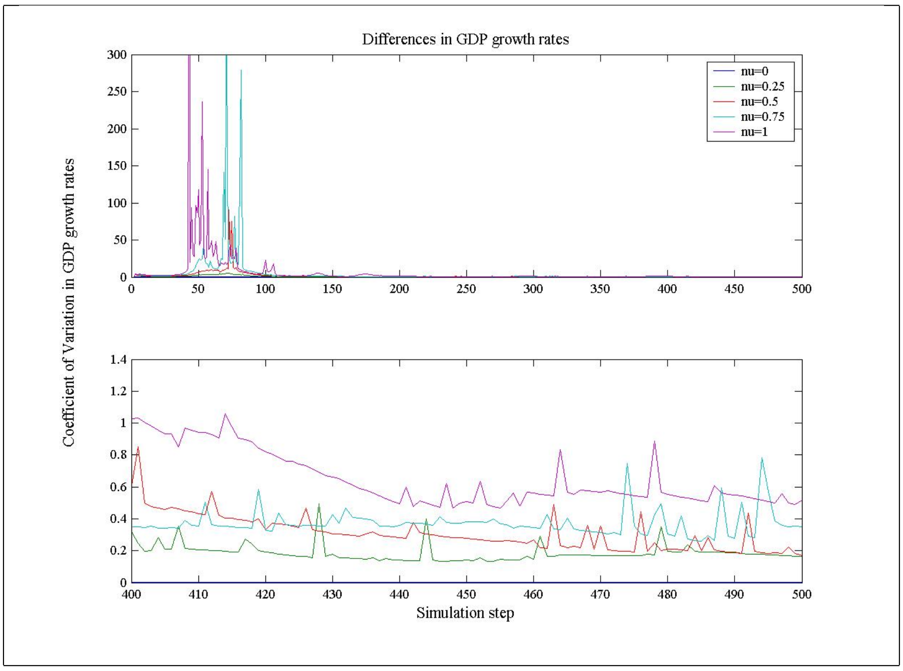

Figure 6.12: Differences in GDP growth rates with various values of ν

differences in GDP growth rates. In this case, these differences are triggered by the micro-dynamics of technical change. Wage dynamics is the channel allowing micro-processes to affect these macro-patterns. The model reproduces here the causal relations to be found in Dosi, Fabiani, Aversi and Meacci, driving growth rates differences. Nevertheless, when considered in absolute terms, growth rates differences generated by these mechanisms remain quite low. When considering the dynamics of the growth rate differences (Figure 6.12), simulation clearly exhibits that the differences in growth concentrates around the first 100 time periods; differences gradually fade and become marginal in the last 100 steps. In this case, differences in GDP growth rates are directly linked to differences in productivity levels. Their transitory nature might be explained by the specialisation process. When specialised, economies have quasi monopolist positions in the sector there specialised in, technology dynamics affect growth through changes in competitiveness that have no more effect on growth in case of monopoly.

Result 16 *Differences in income elasticity significantly affect growth rates differences. In this case differences in GDP growth rates are permanent.*

Figures 6.13 and 6.14 present the patterns of growth rates differences emerging when increasing the heterogeneity of income elasticity among sec-

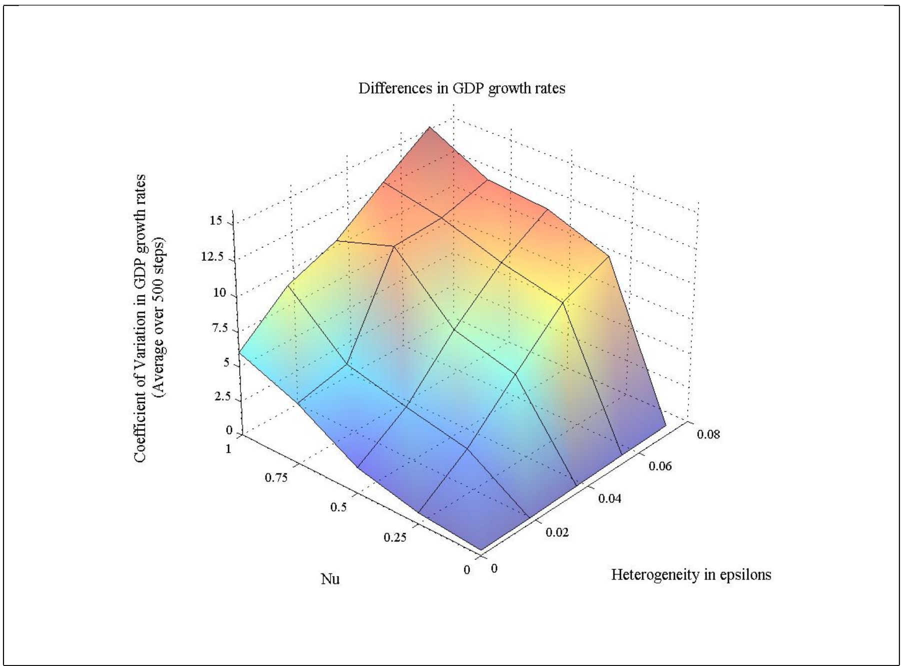

Figure 6.13: Differences in GDP growth rates (Average over 500 steps) with heterogenous income elasticities ($StdDev(\varepsilon_j)$ vs. ν)

tors. The differences in growth are explained by differences in demand characteristics. The income elasticity differences then generate high and low growth path. Specialisation led by technical change then pushes economies on the tracks of one or the other. In this case the model generates growth rate differences patterns in line with the Kaldorian argument, without assuming structural differences in productivity gains. Specialisation and growth differences patterns emerge from the co-evolution of aggregate demand and micro-based technical change. Contrary to the previous parameter configurations, when considering heterogeneous income elasticities, the differences in growth rates are not only transitory. The differences remain significant over time as depicted in Figure 6.14.

Result 17 *Heterogeneity in technological opportunity parameter transitorily affect growth rate difference among economies.*

Figure 6.15 report the patterns of growth rate differences emerging when increasing the heterogeneity in technological opportunities. In this case again, the increasing heterogeneity leads to larger differences in GDP growth rates. Note that in this case the effect is particularly significant when coupled to high values of ν. Technological differences require the inter-sector

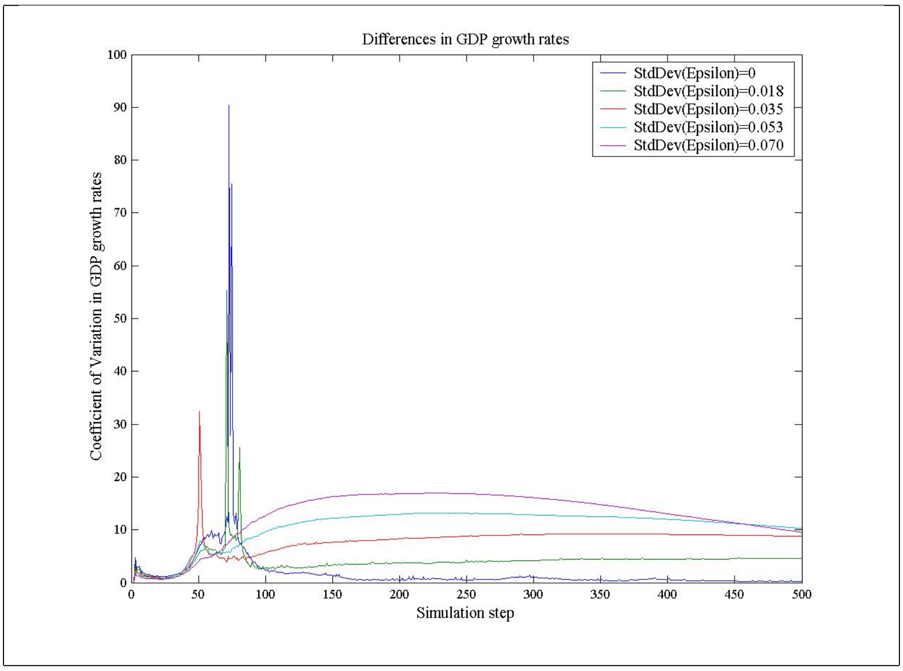

Figure 6.14: Differences in GDP growth rates with heterogeneous income elasticities

selection mechanisms provided by wage dynamics to affect growth rate differences. Note also that for the same reasons than exposed above, these differences in growth rates are only transitory and also fade with the specialisation dynamics leading to sectoral monopolies.

As for specialisation, growing the appropriability of technological spillovers do not exhibit clear patterns in growth rate differences (Figure 6.16).

To summarise the results provided by simulations, we might first stress that the main drivers for specialisation, also generates growth rates differences among economies. Hence, specialisation emerges from the heterogeneity in technical change generated by the micro-dynamics. The latter are amplified by the inter-sector selection process provided at the macro-level by the wage dynamics. These mechanisms also generate growing differences in GDP growth rates. But these differences are concentrated around the first periods and fades while the specialisation process leads to sectoral monopolies.

Second, demand factors also influence the concentration of production in a limited number of sectors, this even when neutralising the effect of technical change at the same time as inter-sector selection. These demand

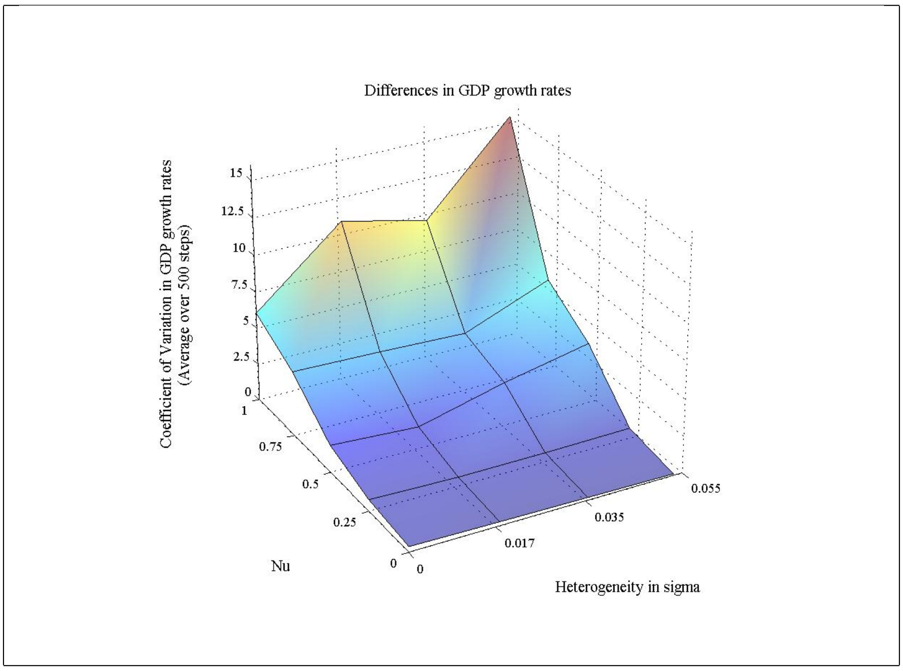

Figure 6.15: Differences in growth rates with heterogeneous σ_j

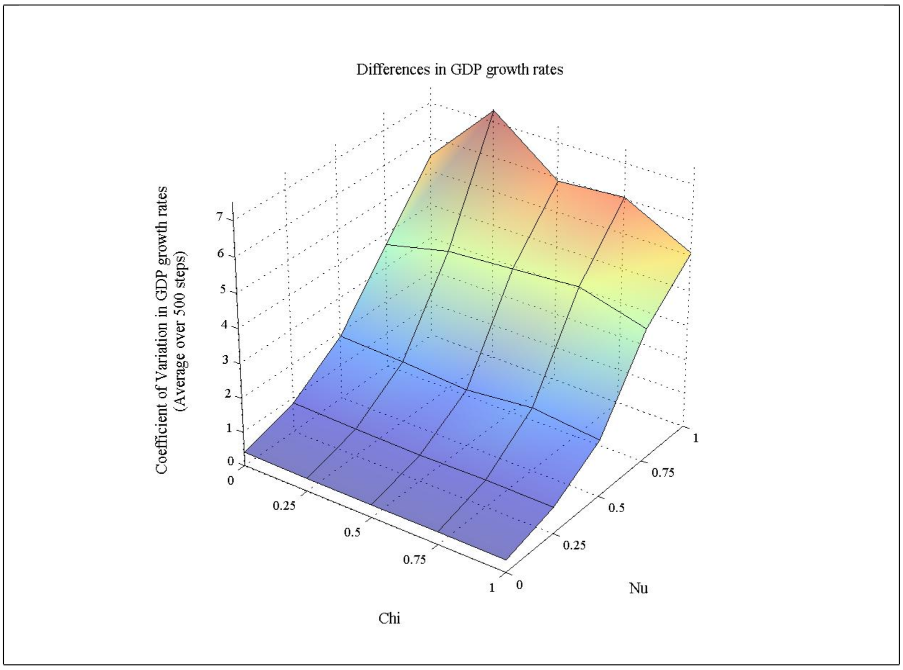

Figure 6.16: Differences in growth rates and appropriability of spillovers

factors as represented by heterogeneous income elasticity also exert a major effect on patterns of growth rates differences. Contrary to the previous cases, differences in GDP growth rates are permanent.

Hence factors leading to specialisation also generate significant differences in GDP growth rates. Two regimes emerge from the simulation, the first is linked to technology dynamics and selection mechanisms and the second is linked to the evolution of the demand structure and demand characteristics. If both generate growth rate differences, in the first regime these are only transitory while in the second they are permanent. This confirms and completes the results previously found with a one-sector model. Table 6.1 sumarises the results found trough the simulations.

Table 6.1: Main Simulation Results

<table>
<tr><th></th><th>$\nearrow \phi$</th><th>$\nearrow StdDev(\bar{\sigma}_j)$</th><th>$\nearrow StdDev(\epsilon_j)$</th><th>$\nearrow \chi$</th></tr>
<tr><td rowspan="2">$\nu \rightarrow 0$</td><td colspan="2">- no specialisation</td><td>-specialisation due to the structure of demand</td><td rowspan="4">No effect</td></tr>
<tr><td colspan="3">- limited growth differencial</td></tr>
<tr><td rowspan="2">$\nu \rightarrow 1$</td><td>-high degree of specialisation</td><td>-limited degree of specialisation</td><td rowspan="2">-high degree of specialisation
-permanent differences in growth rates</td></tr>
<tr><td colspan="2">-transitory differences in growth rates</td></tr>
</table>

6.3 Concluding Remarks

This chapter attempts to pursue the analysis of the determinants of growth rates differences among economies we started in Chapter 5. We propose here a multi-sectoral extension of the model presented in Chapter 5. With this new framework, we consider another dimension in the possible determinants of growth rate differences to be found in the literature: Sectoral specialisation. In both empirical and theoretical literature, a growing number of contributions stresses the importance of patterns of specialisation in explaining these differences. This relationship can be linked to sectoral differences in technological factors, demand factors or both at the same time.

We resort to numerical simulations to address this issue using the framework developed in the second section of this paper. Our investigations focus on the effect of a selected number of parameters on specialisation and growth rate differences patterns. Among these parameters, two are related to the demand factor : price and income elasticity. A third one regulates wage dynamics. The remaining two are linked to technical change.

The results provided by simulation tend to be in line with other existing models. These results are only preliminary and require to be confirmed by a deeper analysis of the model. Still they provide already a few interesting insights.

The main drivers for specialisation, also generates growth rates differences among economies. Specialisation emerges from the differences in productivity gains generated by the micro-dynamics, through an inter-sector selection channel provided by wage dynamics. In our case, the sources of productivity grow are not assumed to structurally differ among sectors, as in Verspagen (1993), Cimoli (1994) or Los and Verspagen (2003). In this sense our model shows that we do not necessary have to assume these structural differences to observe specialisation patterns.

Simulations also emphasise the influence of demand factors on patterns of concentration of production in a limited number of sectors, this even when neutralising the effect of technical change at the same time as inter-sector selection. The influence of the demand structure coupled with the undeniable catalyser mechanisms played by wage dynamics also stress the importance of the macro-frame in diffusing specialisation and growth impulses from micro to macro-dynamics.

Simulation settings

Table 6.2: Key parameters settings (the values by default are in italic)

	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5
ν	0	0	0	0	0
ν	0.05	0.05	0.05	0.05	0.05
ν	0.1	0.1	0.1	0.1	0.1
ν	0.15	0.15	0.15	0.15	0.15
ν	0.2	0.2	0.2	0.2	0.2
ν	0.25	0.25	0.25	0.25	0.25
ν	0.5	0.5	0.5	0.5	0.5
ν	0.75	0.75	0.75	0.75	0.75
ν	1	1	1	1	1
ϕ	0.25	0.25	0.25	0.25	0.25
ϕ	0.5	0.5	0.5	0.5	0.5
ϕ	0.75	0.75	0.75	0.75	0.75
ϕ	*1*	*1*	*1*	*1*	*1*
ϕ	1.25	1.25	1.25	1.25	1.25
ε_j	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*
ε_j	0.175	0.225	0.2	0.2	0.2
ε_j	0.15	0.25	0.2	0.2	0.2
ε_j	0.125	0.275	0.2	0.2	0.2
ε_j	0.1	0.3	0.2	0.2	0.2
σ_j	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
σ_j	0.075	0.125	0.1	0.1	0.1
σ_j	0.05	0.15	0.1	0.1	0.1
σ_j	0.025	0.175	0.1	0.1	0.1
χ_j	0	0	0	0	0
χ_j	0.25	0.25	0.25	0.25	0.25
χ_j	0.5	0.5	0.5	0.5	0.5
χ_j	*0.75*	*0.75*	*0.75*	*0.75*	*0.75*
χ_j	1	1	1	1	1

Table 6.3: Other parameters and initial conditions

	Economy 1	Economy 2	Economy 3	Economy 4	
α_c	0.45	0.45	0.45	0.45	
β_c	0.4	0.4	0.4	0.4	
$Y_{c,t-1}$	100	100	100	100	
$Y_{w,t-1}$	301	301	301	301	
$z_{j,t-1}$	0.25	0.25	0.25	0.25	
	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5
μ_j	0.6	0.6	0.6	0.6	0.6
$\bar{z}_j$	0.001	0.001	0.001	0.001	0.001
$\iota_{i,j,c}$	0.4	0.4	0.4	0.4	0.4
$\rho_{i,j,c}$	0.2	0.2	0.2	0.2	0.2
A_{t-1}	1	1	1	1	1
$w_{j,t-1}$	5	5	5	5	5
$A_{j,t-1}$	1	1	1	1	1
$p_{j,t-1}$	8	8	8	8	8
$p^m_{j,t-1}$	8	8	8	8	8
$z_{i,j,t-1}$	0.0125	0.0125	0.0125	0.0125	0.0125
$A_{i,j,t-1}$	1	1	1	1	1
$a_{i,j,t-1}$	1	1	1	1	1
$K_{i,j,t-1}$	1	1	1	1	1

Chapter 7

Structural Change and Growth Rate Differences

This chapter[1] completes the analysis initiated in the previous chapter. Chapter 6 has stressed the importance of the composition of aggregate demand in shaping the industrial structure but also the divergence patterns among economies. The structure of aggregate demand is, in the model presented in the previous chapter, directly induced by the value of income elasticities. These are fixed for every sectors over time. This assumption implies that for each sector demand can grow indefinitely, with no satiation level nor boundary.

The model presented in this chapter proposes a more elaborated demand structure. This latter is directly inspired by Pasinetti (1981) and Verspagen (1993). In line with these contributions, we assume that for each sector, demand can reach a 'satiation' level or long run share. This long run share corresponds to the upper-limit (or satiation) share of income to be devoted to a given sector. Demand dynamics is defined in such a way that in the actual share of income devoted to a given sector tend to the satiation share in the long run. The speed of convergence to this limit share then depends on the growth rate of income as well as the actual sectoral composition of demand as compared to its long run structure. Moreover we assume that changes in sectoral shares are interdependent. Hence the change in the demand share of a sector does not only depend on its value as compared to the long run value but also on the other sectors position with respect to their own long run value. In other words changes in sectors can be seen as partially integrated, contrary to the previous chapter's model in which sectors demand dynamics

[1]This chapter draws upon a model that has been largely inspired by discussions with B. Verspagen during my stay at ECIS. All usual disclaimer nevertheless apply.

were independent. As we below, the assumptions made on the composition of demand seriously questions some results found previously, especially those ones on the role played by income elasticities in generating permanent differences in GDP growth rates. Finally we choose here to release the balance of payment constraint. This constraint is replaced by the introduction of exchange rates dynamics, which does not drastically affects or questions our previous results.

The chapter is organised as follows: the next section describes the model. Section 7.2 presents and analyses the simulation results.

7.1 A growth model with an evolving demand structure

This section presents a multi-sectoral growth model with interdependent sectors. It considers economic growth as a demand-led process along Kaldorian lines. Contrary to the previous model, GDP growth is not determined by the balance of payment constraint but is defined by the aggregate internal and external demand. Technical change emerges from the micro-dynamics following the evolutionary tradition. Despite the release of the balance of payment constraint the functioning of the model replicates the one presented in the previous chapters. Aggregate demand provides the necessary resources to finance firms' technological development and therefore their competitiveness. Selection among firms and among sectors is rooted in macro-dynamics through demand and wage setting mechanisms. Macro-dynamics generate the financial resources and are responsible for the mechanisms regulating the distribution of the latter across firms. In this sense the macro-frame constraints the micro-dynamics. Micro-dynamics are the core of technological change, and represents one of the engines of growth. The competitiveness of economies, affecting aggregate demand, relies on firms' ability to gain productivity.

The structure of the model can be described as follows. We consider a set of C economies integrated in an economic system through trade relations. An economy $c \in [1; C]$, is referred to with the index c. The variables indexed $\bar{c}$ concern foreign economies with regard to the economy c.

Our system counts J sectors of activity. Each economy can produce and consume products of each sector $j \in [1; J]$.

For each economy, I firms are active in each of the J sectors. A firm $i \in [1; I]$, producing in sector j and based in the economy c is referred to with the indexes i, j, c.

The entire economic system then counts C economies, J sectors, and $C * J * I$ firms. The index t refers to the time step.

7.1.1 Macro-constraints: demand dynamics, wages and exchange rates.

Contrary to the models found in the previous chapters, GDP growth is not determined by the balance of payment constraint. We choose here to release this constraint. Nevertheless, GDP is still considered as demand constrained. Hence, we aggregate sectoral demands to define the level of GDP. The computation of aggregate and sectoral demands, as well as the other macro-components of the model are formally defined as follows.

Aggregate demand:

For each sector j of a given economy c, aggregate demand, in nominal terms, is defined as the sum of two distinct components:

- Domestic consumption ($C_{j,c,t}$), defined as a share ($s_{j,c,t-1}$) of domestic income equal here to GDP ($Y_{c,t}$) allocated to the consumption of sector j products weighted by the market share of the economy in this sector ($z_{j,c,t}$). Formally, domestic consumption ($C_{j,c,t}$) for each sectors are represented as follows:

$$C_{i,j,c,t} = s_{j,c,t-1} Y_{c,t-1} z_{j,c,t} \tag{7.1}$$

- Exports in sector j ($X_{j,c,t}$) corresponds to the share $z_{j,c,t}$ of the sum of foreign economies imports of sector j products. The latter correspond to the share $(1 - z_{j,c,t})$ of consumption of sector j not covered by domestic firms. Hence, exports ($X_{j,c,t}$) for each sectors are formally described as follows:

$$X_{j,c,t} = z_{j,c,t} \sum_{\bar{c}} M_{j,\bar{c},t-1}$$

$$X_{j,c,t} = z_{j,c,t} \sum_{\bar{c}} e_{\bar{c},t-1} s_{j,\bar{c},t-1} Y_{\bar{c},t-1} (1 - z_{j,\bar{c},t}) \tag{7.2}$$

The share of income devoted to the consumption of each sector's products $s_{j,c,t}$ is defined as follows. We assume here, following Pasinetti (1981) and Verspagen (1993), that sectors dynamics are interrelated. Each sector is characterised by an intrinsic or long run share of demand. Every sector tend to this long run share through time, but the evolution of final demand for every sector is a function of the other sector's evolution. In this sense we introduce some degrees of complementarity in the dynamics of sector's demand. More formally the share of income $s_{j,c,t}$ devoted to sector j products grows proportionally to income growth. As income grows this share tends towards the long run share $\bar{s}_j$.

$$s_{j,c,t} = s_{j,c,t-1}\left(1 + \frac{\partial s_{j,c,t}}{\partial Y_{c,t}} \frac{\Delta Y_{c,t}}{Y_{c,t-1}}\right) \tag{7.3}$$

with

$$\frac{\partial s_{j,c,t}}{\partial Y_{c,t}} = s_{j,c,t-1} \sum_{\bar{j}} b_{\bar{j}j}(s_{\bar{j},c,t-1} - \bar{s}_{\bar{j}}) - (s_{j,c,t-1} - \bar{s}_j) \sum_{\bar{j}} b_{j\bar{j}} s_{\bar{j},c,t-1} \tag{7.4}$$

Hence, the convergence of $s_{j,c,t}$ towards the long run share $\bar{s}_j$ is also function of the evolution of the other sectors' shares $s_{\bar{j},c,t}$ towards their own long run shares $\bar{s}_{\bar{j}}$. The parameters $b_{\bar{j}j}$ and $b_{j\bar{j}}$ capture the degree of interdependence in sectors' shares evolution. The long run shares $\bar{s}_j$ are defined as follows:

$$\bar{s}_j = \frac{\theta_j}{\sum_j \theta_j}$$

Each sector j has an intrinsic value measured by θ_j. To simplify the model, θ_j are exogenous. This value can be explained by institutional or cultural factors. The parameter θ_j can be subject to exogenous changes. We introduce random changes in the long run demand structure of our economies using stochastic changes in the value of this parameter (see Section 7.2.2). These changes therefore trigger structural change.

The market share of the economy in a sector is a proxy for the price competitiveness of the economy in the sector. It is given by the sum of the market shares of the domestic firms active in this sector:

$$z_{j,c,t} = \sum_i z_{i,j,c,t}$$

Each firm's market shares is defined through a replicator dynamic, function of firm's relative competitiveness. Hence the market share of each firm will be computed as follows:

$$z_{i,j,c,t} = z_{i,j,c,t-1}\left(1 + \phi\left(\frac{E_{i,j,c,t}}{\bar{E}_{j,t}} - 1\right)\right)$$

where $z_{i,j,c,t}$ represents the market share of firm i, $p_{i,j,c,t}$ the price of its product. $E_{i,j,c,t}$ stands for firm i, in sector j level of competitiveness:

$$E_{i,j,c,t} = \frac{1}{e_{c,t-1}p_{i,j,c,t}}$$

$e_{c,t-1}$ represents the exchange rate defining the value of the domestic currency in terms of a foreign reference currency.

$\bar{E}_{j,t}$, the average competitiveness on the international market, is computed as follows:

$$\bar{E}_{j,t} = \sum_{c,i} z_{i,j,c,t-1}E_{i,j,c,t}$$

For each sector j the aggregate output ($Q_{j,c,t}$) is constrained by the level of demand ($D_{j,c,t}$):

$$D_{j,c,t} = Q_{j,c,t} \equiv \sum_{i} Q_{i,j,c,t}$$

The level of demand of sector j corresponds to the sum of domestic and external demand. The latter are computed respectively as the level of domestic consumption ($C_{j,c,t}$) deflated by the domestic price level ($p_{j,c,t}$) and the level of exports ($X_{j,c,t}$) deflated by the domestic price level multiplied by the exchange rate ($e_{c,t-1}p_{j,c,t}$). Formally each sector j level of demand[2] is therefore defined as follows:

$$D_{j,c,t} = \frac{C_{j,c,t}}{p_{j,c,t}} + \frac{X_{j,c,t}}{e_{c,t-1}p_{j,c,t}}$$

$$D_{j,c,t} = \frac{z_{j,c,t}}{p_{j,c,t}}\left[s_{j,c,t-1}Y_{c,t-1} + \sum_{\bar{c}} \frac{e_{\bar{c},t-1}}{e_{c,t-1}} s_{j,\bar{c},t-1}Y_{\bar{c},t-1}(1 - z_{j,\bar{c},t})\right] \tag{7.5}$$

At this point we can define the level of GDP of an economy c ($Y_{c,t}$) in nominal terms as follows:

$$Y_{c,t} = \sum_{j} p_{j,c,t}Q_{j,c,t}$$

Replacing the level of output ($Q_{j,c,t}$) of each sectors by the expression given by equation 7.5, we obtain an expression of the GDP level as a function of the economies levels of income :

$$Y_{c,t} = \sum_{j}\left(s_{j,c,t-1}Y_{c,t}z_{j,c,t} + \frac{z_{j,c,t}}{e_{c,t-1}}\sum_{\bar{c}} e_{\bar{c},t-1}s_{j,\bar{c},t-1}Y_{\bar{c},t}(1 - z_{j,\bar{c},t})\right)$$

$$Y_{c,t} = \frac{1}{1 - \sum_j s_{j,c,t-1}z_{j,c,t}} \sum_{\bar{c}} \frac{e_{\bar{c},t-1}}{e_{c,t-1}} Y_{\bar{c},t} \sum_{j} z_{j,c,t}s_{j,\bar{c},t-1}(1 - z_{j,\bar{c},t}) \tag{7.6}$$

[2]All the intermediate mathematical computations are provided in the appendix.

Trade balance and exchange rate dynamics:

Contrary to the previous chapters we release here two assumptions on the functioning of international trades; namely the assumption of fixed exchange rates and the balanced trade assumption. We introduce an explicit exchange rates ($e_{c,t}$) dynamics. The latter is directly correlated to changes in the trade balance ($B_{c,t}$). Formally exchange rates dynamics is represented by the following equation:

$$e_{c,t} = e_{c,t-1}\left(1 + \beta \frac{B_{c,t}}{Y_{c,t}}\right) \tag{7.7}$$

The exchange rates dynamics as defined here replicate the idea that trade balance desequilibria, normalised by GDP ($\frac{B_{c,t}}{Y_{c,t}}$) implies capital (or asset) flows influencing exchange rates. The parameter β catalyses this effects in such a way that the smaller β is, the more rigid exchange rates are. Conversely the larger β, the more sensitive to changes in the trade balance the exchange rates are.

Trade balance is logically computed as follows:

$$B_{c,t} = \sum_j X_{j,c,t} - \sum_j M_{j,c,t}$$

$$B_{c,t} = \sum_j z_{j,c,t} \sum_{\bar{c}} s_{j,\bar{c},t-1} Y_{\bar{c},t-1} - \sum_j (1 - z_{j,c,t}) s_{j,c,t-1} Y_{c,t-1} \tag{7.8}$$

Wage determination:

Wages are set at the sectoral level. For a given sector j wage dynamics will be correlated to sector j productivity growth rate ($\frac{\Delta A_{j,c,t}}{A_{j,c,t-1}}$) and to the entire economy productivity growth rate ($\frac{\Delta A_{c,t}}{A_{c,t-1}}$). The effect of these two variables on wage dynamics is weighted by the parameter $\nu \in [0; 1]$, such that :

- When $\nu = 1$, the wage dynamics for every sector only depend on the macro-level productivity growth rate. (i.e. as a centralised wage negotiation system)

- When $\nu = 0$, the wage dynamics for every sector only depend on the sector-level productivity growth rate. (i.e. as a decentralised wage negotiation system)

Wage dynamics of the sector j, in the economy c is represented as follows:

$$\frac{\Delta w_{j,c,t}}{w_{j,c,t-1}} = \nu \frac{\Delta A_{c,t}}{A_{c,t-1}} + (1 - \nu) \frac{\Delta A_{j,c,t}}{A_{j,c,t-1}} \tag{7.9}$$

With

$$A_{c,t} = \frac{Q_{c,t}}{L_{c,t}} \text{ and } A_{j,c,t} = \frac{Q_{j,c,t}}{L_{j,c,t}}$$

Note that the wage level defined by this process during the period t is applied by firms at period $t+1$. Wage dynamics in our model act as a second macro-constraint on firms. Hence, they affect directly firms competitiveness and the selection mechanisms on firms. Firms in a given sector will loose competitiveness if their own productivity growth rate is slower then the average one. Moreover, when $\nu \neq 0$, wage dynamics generate a selection process among sectors. Hence, if the average productivity of a sector grows slower then the average productivity growth rate of the entire economy, through wage dynamics, this sector looses competitiveness. The amplitude of this effect directly depends on the value of the parameter ν. As argued in the last section of this paper wage dynamics through the process described above play a major role in the specialisation dynamics.

7.1.2 Firm level dynamics and the micro-foundations of technical change: A reminder

This subsection is devoted to the description of the microeconomic functioning of the model. As for the previous chapter, the micro-dynamics draw largely on the one presented in Chapter 4.

We consider here the formal representation of firms' production capacities, investment decisions and R&D activity. Note that the representation provided applies to all sectors and economies. Sectoral or economy-wide specificity, when considered, take the form of specific parameter values.

The micro-foundations of the model can be summarised as follows. We consider a population of bounded rational firms that differ in their technological characteristics. Technical change emerges at the firm level as a mutation process. More precisely technical change is embodied in capital vintages developed by firms to build and improve their production capacities.

Satisfying demand provides firms with the financial resources to sustain the development of their production capacities, through investments in capital goods and R&D. This generates technical change.

Defining firms characteristics:

Firms' production process is represented by a Leontiev production function with labour as unique production factor. Capital goods are not used as input but enter the production function in defining labour productivity. Each capital good embodies a level of labour productivity. Hence investment in the different vintages of capital goods modifies the labour productivity of the firm. The production function is represented as follows :

$$Q_{i,j,c,t} = A_{i,j,c,t-1} L_{i,j,c,t} \tag{7.10}$$

where $Q_{i,j,c,t}$ is the output of firm i, producing in sector j at time t. $A_{i,j,c,t-1}$ represents labour productivity and $L_{i,j,c,t}$ the labour force employed in the production process. Output is constrained by the demand directed to the firms and defined at the macro-economic level. The level of production of each firm is computed as a share of sector j demand given by their relative market share such as:

$$Q_{i,j,c,t} = \frac{z_{i,j,c,t}}{z_{j,c,t}} D_{j,c,t}$$

Labour productivity is a function of the firms' accumulation of capital goods through investment, so that at the end of any period t :

$$A_{i,j,c,t} = \frac{I_{i,j,c,t} a_{i,j,c,t-1}}{\sum_{\tau=1}^{t} I_{i,j,c,\tau}} + \frac{\sum_{\tau=1}^{t-1} I_{i,j,c,\tau}}{\sum_{\tau=1}^{t} I_{i,j,c,\tau}} A_{i,j,c,t-1} \tag{7.11}$$

where $a_{i,j,c,t-1}$ represent the labour productivity embodied in the capital good developed by the firm i during the period $t-1$. $I_{i,j,c,t}$ represents the level of investment in capital goods of the firm.

Firms set prices through a mark-up process. This mark-up is applied to labour cost linked to the production process. For the sake of simplicity the labour costs linked to R&D activity are funded by profits. Prices can thus be represented as follows:

$$p_{i,j,c,t} = (1 + \mu_j) \frac{w_{j,c,t-1}}{A_{i,j,c,t-1}} \tag{7.12}$$

where $p_{i,j,c,t}$ represents the price set by firm i at time t, μ_j the mark-up coefficient and $w_{j,t-1}$ the wage level set at the macro level for the entire sector. Note that we assume here that the mark-up coefficients are fixed for each firm in a given sector of a given economy.

Firm's profit level will then be computed as follows:

$$\Pi_{i,j,c,t} = p_{i,j,c,t} Q_{i,j,c,t} - w_{j,c,t-1} L_{i,j,t} = (1 + \mu_j) \frac{w_{j,c,t-1}}{A_{i,j,c,t-1}} Q_{i,j,c,t} - w_{c,t-1} \frac{Q_{i,j,c,t}}{A_{i,j,c,t-1}}$$

$$\Pi_{i,j,c,t} = \mu_j \frac{w_{j,c,t-1}}{A_{i,j,c,t-1}} Q_{i,j,c,t} \tag{7.13}$$

In the model, profits represent the only financial resource for firms' investments.

Investment decisions and technical change:

As introduced previously, firms have to accumulate capital vintages to build up and improve their production capacities. Each capital good is developed in-house by firms and then introduced in their production technologies. This process is decomposed in two phases. First firms explore and develop new capital goods, through local search or through the adaptation of existing capital goods to their own production techniques. This phase takes place within the R&D activity of the firms. The latter is financed by investments in R&D. The second stage consists in introducing the outcome of the R&D activity within the production process. This stage is costly and requires firms to invest in the exploitation of the latest capital good vintage. The level of investment determines the relative importance of the latest capital goods in the production process and therefore determines the actual productivity gains, as described above. These two distinct investments are subject to the firms financial constraint. Firms' only resources for investments are their profits. More profitable firms are more inclined to invest and therefore to improve their production capacities and their competitiveness.

The investment decision timing is set as follows. First firms invest in capital goods, in order to gain from the already developed vintages, and then invest in R&D.

Investment in capital goods corresponds to a share $\iota_{i,j,c}$ of firms' sales. Given the financial constraint the investment level in capital good is formally represented as follows:

$$I_{i,j,c,t} = min\,\{\iota_{i,j,c}Q_{i,j,c,t}\ ;\ \Pi_{i,j,c,t}\} \tag{7.14}$$

Investments in R&D are a share $\rho_{i,j,c}$ of their sales. R&D investment will correspond to the hiring of workers assigned to the research activity :

$$R_{i,j,c,t} = \frac{1}{w_{j,c,t-1}} \min\{\rho_{i,j,c}Q_{i,j,c,t}; \Pi_{i,j,c,t} - I_{i,j,c,t}\} \tag{7.15}$$

The formal representation of the R&D process is explicitly inspired by evolutionary modelling of technical change. Following Nelson and Winter (1982) we consider that the probability of success of research is an increasing function of R&D investments. Formally the R&D activity is represented by the following algorithm:

1. Firms draw a number from a Uniform distribution on [0 ; 1].
2. If this number is contained in the interval $[0\ ;\ \frac{R_{i,j,c,t}}{Q_{i,j,c,t}}]$, the R&D is successful. Hence a new capital good vintage has been developed.

3. If R&D is successful, its outcome is drawn from the following distribution. We differentiate here explicitly innovative firms from imitative ones:

$$a_{i,j,c,t} = \max\left\{a_{i,j,c,t-1} + \epsilon_{i,j,c,t}; a_{i,j,c,t-1}\right\} \tag{7.16}$$
$$\epsilon_{i,j,c,t} \sim N(0; \sigma_{i,j,c,t}) \tag{7.17}$$

$$\text{with} \begin{cases} \sigma_{i,j,c,t} = \sigma_{j,c} & \text{if the firm is an innovator} \\ \sigma_{i,j,c,t} = \chi_{j,c}(\bar{a}_{j,t} - a_{i,j,c,t}) & \text{if the firm is an imitator} \end{cases} \tag{7.18}$$

The outcome of the R&D process defines the labour productivity level embodied in the newly discovered capital vintage ($a_{i,j,c,t}$). $\bar{a}_{j,t}$ represents the average productivity level embodied in the latest capital vintages developed by firms. It is formally computed as:

$$\bar{a}_{j,t} = \sum_{i,c} z_{i,j,c,t} a_{i,j,c,t-1}$$

Hence $\bar{a}_{j,t} - a_{i,j,c,t}$ represents firm i, j, c technological gap, while the parameter $\chi_{j,c} \in [0;1]$ can be seen as the degree of access to spillover for the imitating firms.

Firms exit the market if their market share is lower then $\bar{z}_j$. They are replaced by firms characterised by the average values of the variables for the sector and a market share equal to $\bar{z}_j$. As a consequence the number of firms remains constant. An exiting innovator is replaced by an entrant innovator, and an exiting imitator by an entrant imitator. Thus the proportion of innovators and imitators remains constant.

7.2 Simulation Results

As for the previous models, we make use of numerical simulations to analyse the dynamics generated by the model. Our aim is to complete the analysis started in Chapter 6, on the relation between patterns of specialisation and growth rates differences. We therefore choose a similar simulation procedure to conduct the analysis. No ad-hoc assumptions are made on specialisation patterns nor initial differences in GDP growth rates. All objects composing the model are set similarly at the initial period. Specialisation patterns are treated as emergent properties of the model. We therefore aim to isolate the key mechanisms generating these patterns.

Two distinct regimes of specialisation emerged from Chapter 6. First, the uneven nature of technical change among firms and sectors, reinforced by the cumulative nature of productivity gains, leads to the emergence of specialisation patterns when coupled to a catalyser generating an inter-sector selection mechanism. Wage dynamics play such a role of catalyser (Result 12). The second regime is completely demand-led. Economies concentrate their production in the sectors with the most dynamic demand growth. These sectors are characterised by the highest income elasticity (Result 13). In both cases specialisation led to significant growth rates differences. These differences were only transitory if the income elasticities were identical among sectors (Result 17). If sectors were characterised by different levels of income elasticities then not only the differences in GDP growth rate became persistent, but the range of the differences was directly shaped by the amplitude of the differences in income elasticities (Result 16).

We claim here that the emergence of this second regime and the persistence of the growth rates differences are linked to the fixed values of the income elasticities. We therefore aim to analyse the effect of sectoral heterogeneity in the 'satiation' levels, and of the speed of structural change on specialisation and growth rates differences. As in the previous chapter the degree of specialisation of the economies is measured by the average (across economies) inverse Herfindahl index. Divergence patterns are measured using the coefficient of variation in both real and nominal GDP. The analysis of simulation results is organised as follows. In the next sub-section we consider the effect of heterogeneity in satiation level among sectors (i.e. through the parameters θ_j), and speed of convergence of sector's demand share towards their satiation levels (i.e. through the parameters $b_{\bar{j}j}$). This effect is analysed in two cases: in the first case we neutralise the specialisation mechanisms due to the competition factors. In the second case, these mechanisms are perfectly working. In a second subsection we analyse the effect of demand shocks on the patterns of structural change and growth rates differences, as previously found, controlling for the frequency and amplitude of the demand shocks. Again, we differentiate the case in which specialisation mechanisms are neutralised and the one in which this mechanism perfectly work.

Simulations are organised as follows. Our artificial world contains 2 economies and 4 industrial sectors. Each economy is producing and consuming products from each of these sectors. Each sector counts 20 firms, 10 from the first economy and the other 10 from the second. Every simulation run lasts 1000 periods. We choose in this case longer time periods to generate structural change. Finally, every simulation setting is replicated 20 times. The results presents the average outcome over 20 replications. As for the previous chapters, all the firms and economies are initially similar. The differences in GDP growth rates as well as in the structure of the economies are therefore emerging from the dynamics generated by the model.

7.2.1 Demand characteristics and growth rate differences:

We present the results of the simulations when considering the effect of changes in demand characteristics in terms of specialisation and growth rates differences patterns. We focus here on two of sectoral demand characteristics:

- *Heterogeneity in θ's*; this parameter defines the long run values of sectors' demand share. The degree of heterogeneity of θ therefore defines the degree of heterogeneity in these long run shares.

- $b_{\bar{j}j}$; this parameter controls simultaneously for the degree of inter-sectoral interdependence in the demand shares dynamics, and the speed of convergence of the latter towards their long run values. We assume here to simplify the analysis that $b_{\bar{j}j} = b_{j\bar{j}} = b$. There are no differences in terms of interdependence among sectors. The analysis therefore focuses on the speed of convergence towards the long run shares.

We introduce structural differences among sector's demand through the increase in the heterogeneity in θ. This replaces the structural differences introduced in the Chapter 6 by the differences in income elasticities. We analyse the effect of the changes in these demand parameters considering two specification of the parameter ν.

A first set of simulations results presents the effect of the changes in the demand parameters on the macro-dynamics when the parameter $\nu = 0$. In this case we neutralised the micro-to-macro transmission mechanisms played by wages. The differences in productivity among sectors are therefore absorbed by wages. We therefore prevent the process of international specialisation.

Figure 7.1 presents the effect on the average inverse Herfindahl index after 1000 steps of changes in the demand parameters. This index measures the degree of specialisation of the economies. It estimates the average number of sectors in which the economies are producing. If increasing the heterogeneity in θ seems to increase specialisation, this influence is however limited. Hence, the index, as shown by Figure 7.1, does not go below 3. In other words, the changes in demand parameters do not significantly affect the structure of production, contrary to the results found in Chapter 6, when considering changes in income elasticities.

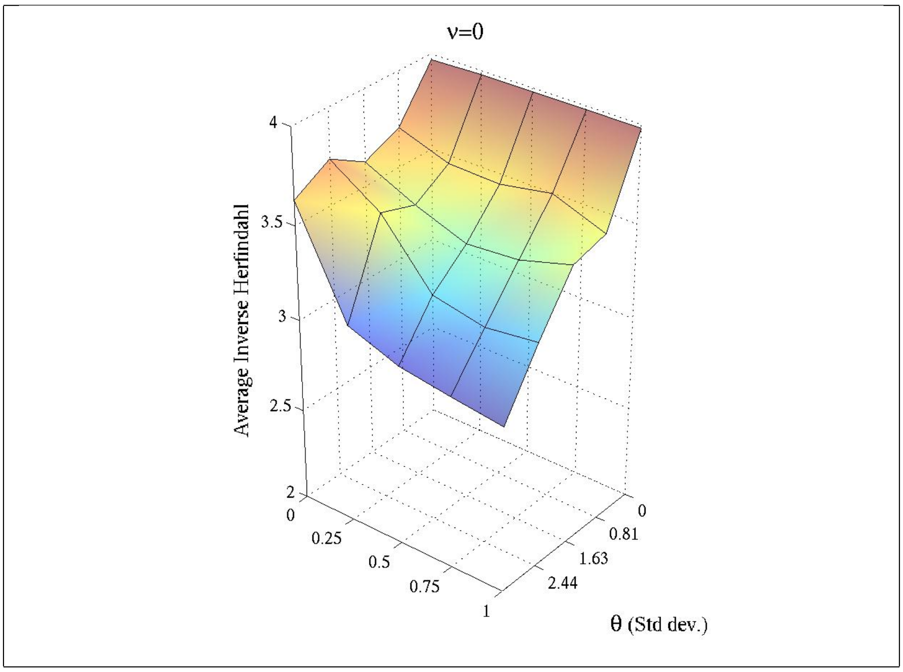

Figure 7.1: Average inverse Herfindahl (Step 500), $b_{\bar{j}j}$ vs. Std dev.(θ), $\nu = 0$.

Figure 7.2 presents the effect of changes in demand parameters on growth rates differences as measured using the average coefficient of variation in real GDP growth rates over 1000 simulation steps. On the one hand, increasing the heterogeneity in θ clearly and significantly affect growth rates differences. On the other hand, increasing the speed of convergence toward the satiation levels do not exhibit a clear pattern in affecting the growth rates differences.

To sum up, this first set of simulations leads to the following results:

Result 18 *Changes in the demand characteristics do not clearly affect the sectoral structure of the economies, when competition factors leading to specialisation are neutralised. Increasing the heterogeneity in the 'satiation' levels, however, significantly affects the growth rates differences, but this effect fades away, once the 'satiation' levels are reached.*

These findings can be explained as follows. Both the influence on the sectoral structure and on growth differences linked to demand characteristics found in Chapter 6 were directly linked to the persistence of the differences in income elasticities. This chapter allows for income elasticity to change endogenously as GDP grows. For each sector, the income elasticity is a function of the gap between the actual and the long run demand shares. Differences in income elasticities across sectors are therefore function of the

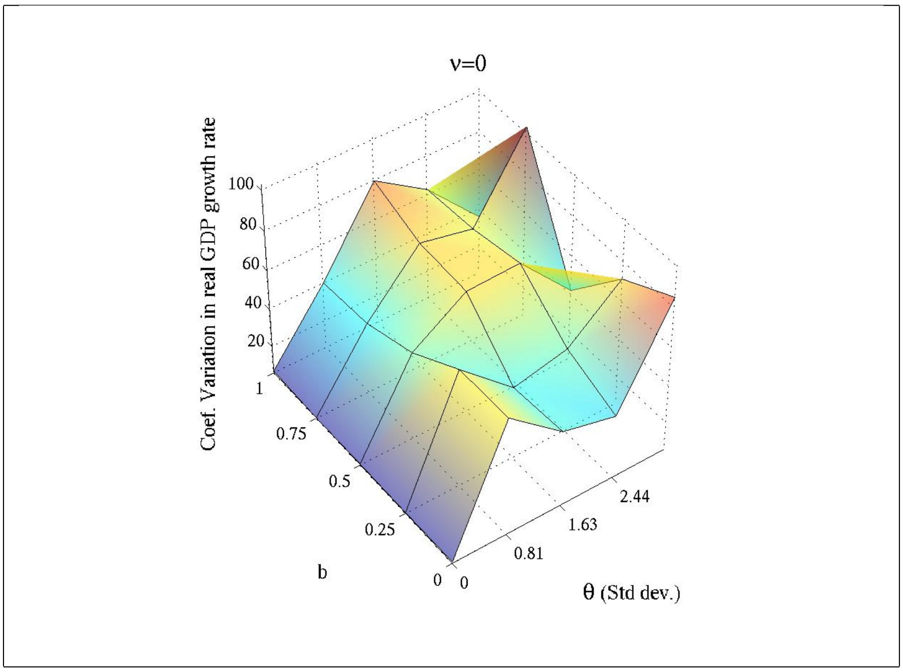

Figure 7.2: Coefficient of variation in real GDP growth rates, $b_{\bar{j}j}$ vs. Std dev.(θ), $\nu = 0$.

differences in the values of these gaps. As GDP grows, these gaps are fulfilled. When the satiation levels are reached, each sector's income elasticity equals to one, and there are no more differences in income elasticities. The effect of the differences in demand characteristics then disappears. The growth differentials are then only due to technological shocks. The latter, as shown in the previous chapters, only transitorily affect macro-dynamics (see Result 17. This transitory effects are even limited by ν being equal to zero.

These mechanisms can be illustrated by the example of simulation run presented in Figures 7.4, 7.3 and7.5. During the first 500 steps, as no specialisation occurs, the GDP growth rates change according to the increase in demand shares and in market shares. The differences, however gradually fade away. After the 500th step, when the demand shares have almost reached the satiation level (Figure 7.4), the differences in GDP growth rates (Figure 7.5) corresponds exactly to changes in the market shares (Figure 7.3).

The second set of simulations proposes the same parameter settings for the demand characteristics but with $\nu = 1$. In this second case, wage dynamics favours sectoral specialisation through international competition. Wages grow at the same rate as the average productivity of the economy. The sectors with productivity growth rates higher than the average therefore gain

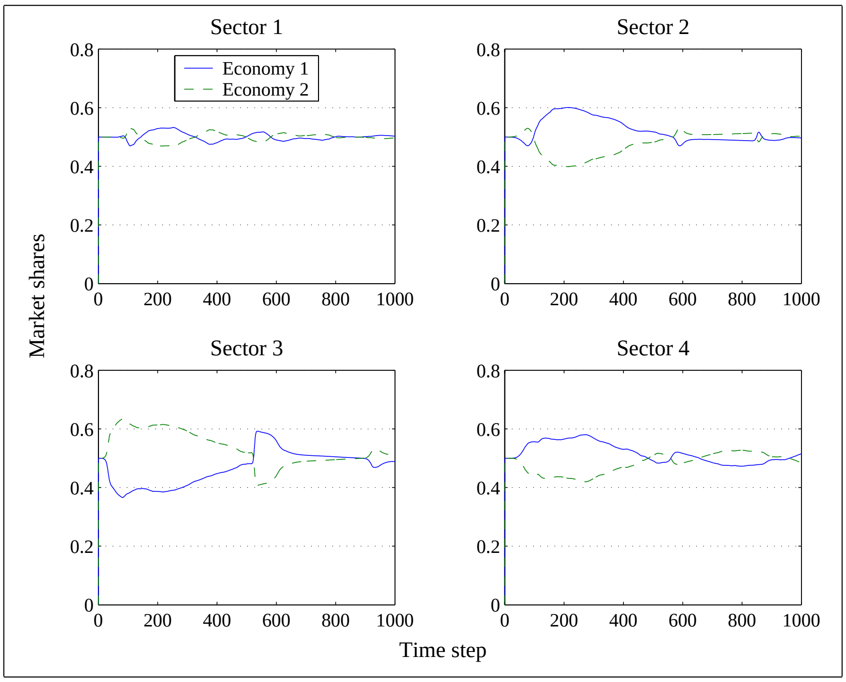

Figure 7.3: Market shares (example) $b_{\bar{j}j} = 0.5$, Std dev.$(\theta) = 1.65$, $\nu = 0$.

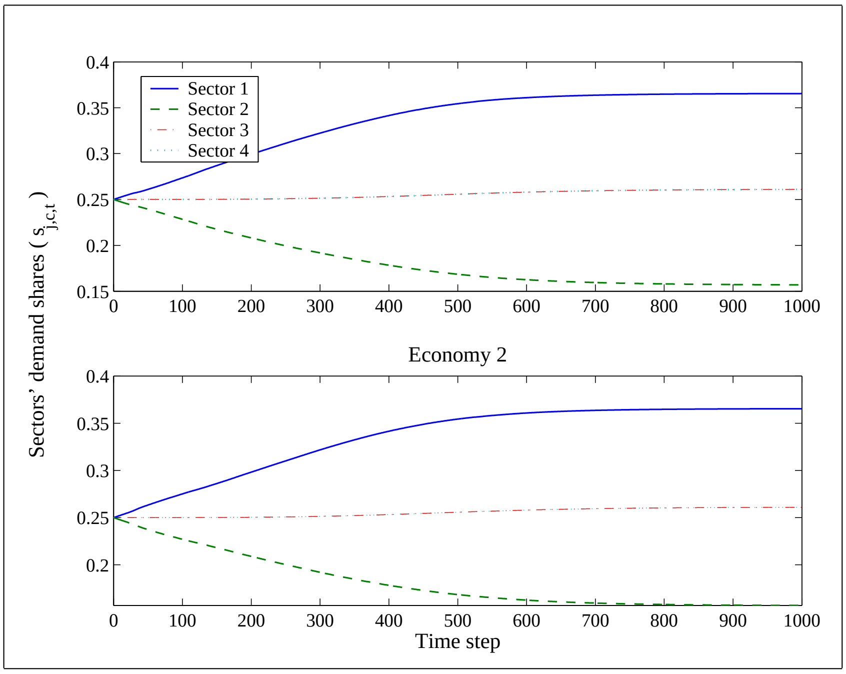

Figure 7.4: Sectors' demand shares (example) $b_{\bar{j}j} = 0{,}5$, Std dev.$(\theta) = 1{,}65$, $\nu = 0$.

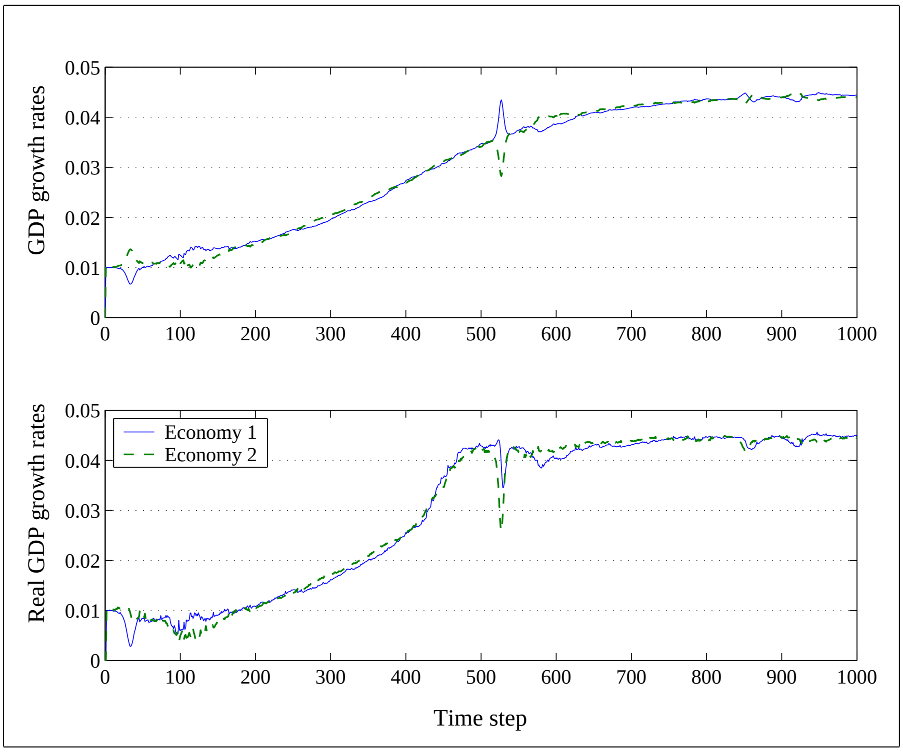

Figure 7.5: GDP growth rates (example run) $b_{\bar{j}j} = 0.5$, Std dev.$(\theta) = 1.65$, $\nu = 0$.

in competitiveness, the other loose competitiveness. International competition mechanisms are then such that the economies specialise in their most competitive sectors. As we show in Chapter 6, when sectors have different income elasticities, specialisation favours growth rates differences among economies. We here test the effect of changes in demand characteristics when specialisation is allowed by wages dynamics.

Figure 7.6 presents the effect of the changes in demand characteristics on the differences in GDP growth rates measured by the average coefficient of variation among the 1000 simulation steps. Increasing the heterogeneity in θ clearly increases the growth rates differences among economies. Similarly, increasing the speed of convergence of the demand shares towards their long run values rises the coefficient of variation in both nominal and real GDP growth rates. The differences in GDP growth rates, as measured, with $\nu = 1$ are at their maximum twice as big as the one measured when $\nu = 0$.

As in Chapter 6, specialisation favours growth rates differences when there exists heterogeneity in sectors' demand characteristics. FIgure 7.7 reports the effect of the modifications in demand characteristics on the average inverse Herfindahl index. The values clearly show that specialisation occurs.

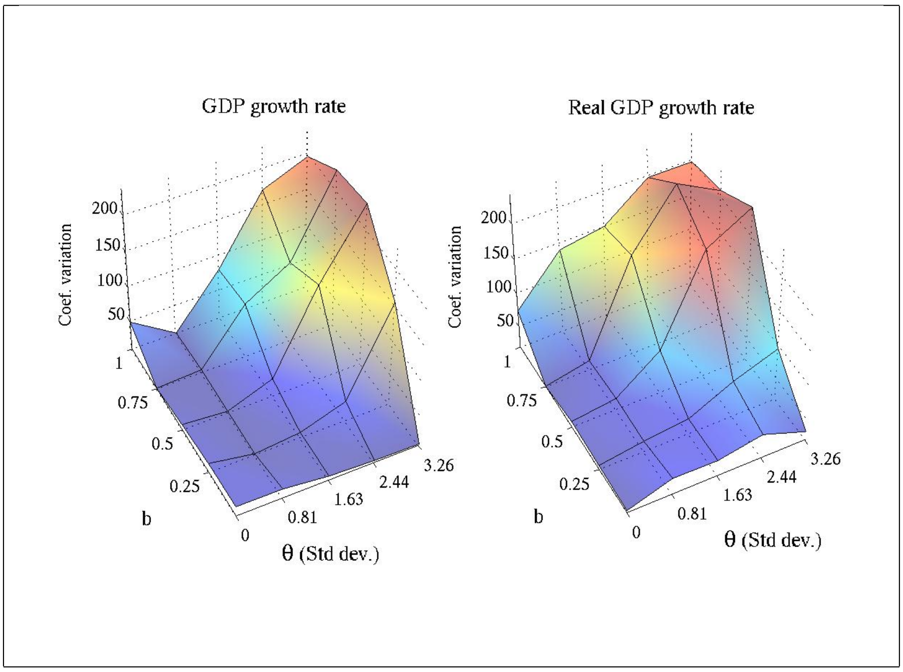

Figure 7.6: Coefficient of variation in GDP growth rates, $b_{\bar{j}j}$ vs. Std dev.(θ), $\nu = 1$.

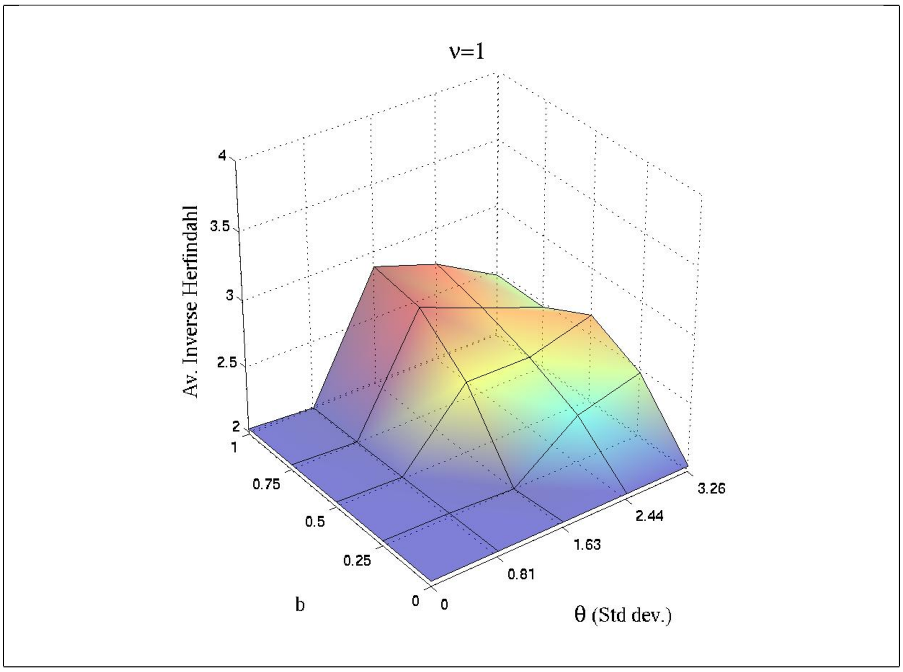

Figure 7.7: Average inverse Herfindahl, $b_{\bar{j}j}$ vs. Std dev.(θ), $\nu = 1$.

However, simulations also exhibits that for higher degrees of heterogeneity in θ and high values of b, the level of specialisation seems to decrease. This in turn corresponds to the emergence of a de-specialisation phase, as shown by Figure 7.8.

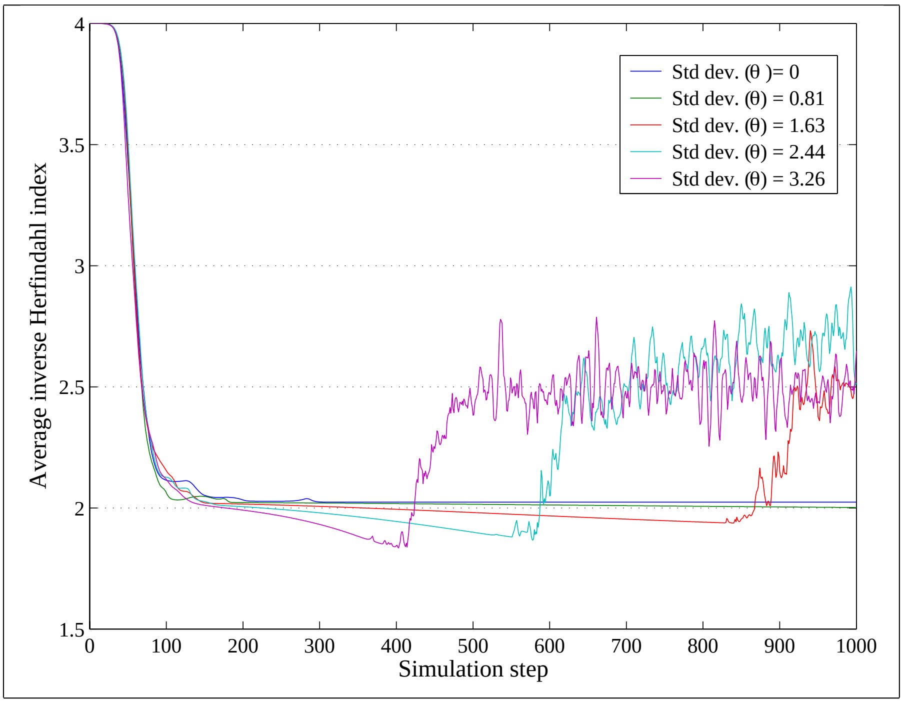

Figure 7.8: Average Herfindahl index dynamics, $b_{\bar{j}j} = 0.5$, $\nu = 1$.

To sum of, this second set of simulations leads to the following results:

Result 19 *Specialisation occurs only through market competition channels. When specialisation occurs, the growth differential is significantly higher, it however remains transitory. Specialisation is itself transitory. When the gains of specialisation disappear, reaching the satiation levels, economy tend to de-specialise.*

These results can be explained as follows. When specialisation occurs, and that sectors have heterogeneous demand characteristics, this leads GDP growth rates differences. The economies specialising in the favoured sectors in terms of demand parameters grow faster than the others. Specialising in sectors with the highest demand dynamics implies higher resources available to invest. These favour the adoption of more efficient production designs by firms, and therefore allows for gains in productivity and competitiveness. These gains reinforces the mechanisms which leads to specialisation. Specialisation is then a self-sustained process.

Due to the changes in the modelling of sectors' demand and the introduction of 'satiation' levels, income elasticities change through time. As GDP grows, each sector's income elasticity tends to one, when reaching these 'satiation' levels. As the gap between the actual and the long run demand shares reduces, the gains of specialisation (i.e. the resources differentials) gradually disappear. Specialisation is therefore no more self-reinforced. The emergence of technological shocks can then lead to changes in the leadership of certain sectors, as well as changes in the competitiveness "hierarchy" among sectors of the same economy. These two process explains the emergence of a de-specialisation process. The differences in GDP growth rates are then only linked to technological shocks and, as seen in Chapter 6 these are only transitory.

These mechanisms can be illustrated by the Figure 7.9, 7.10 and 7.11 which present the outcome of an example of simulation run. The parameters setting used in this example is such that the Sector 1 has the highest long-run share, and Sector 2 the lowest. Specialisation occurs during the first 200 steps. Sectors are allocated as follows: Economy 1 specialises in Sector 1 and 4. Economy 2 specialises in Sector 2 and 3 (see Figure 7.10). This specialisation pattern clearly affects GDP growth rates (Figure 7.9). Economy 2 experiences a lower growth rate. The growth differential gradually reduces until the sectors demand reach their long run values between the 500th and the 600th step (Figure 7.11).

Once the demand stabilises around the satiation levels, the differences in GDP growth rates (Figure 7.9) corresponds exactly to changes in the market

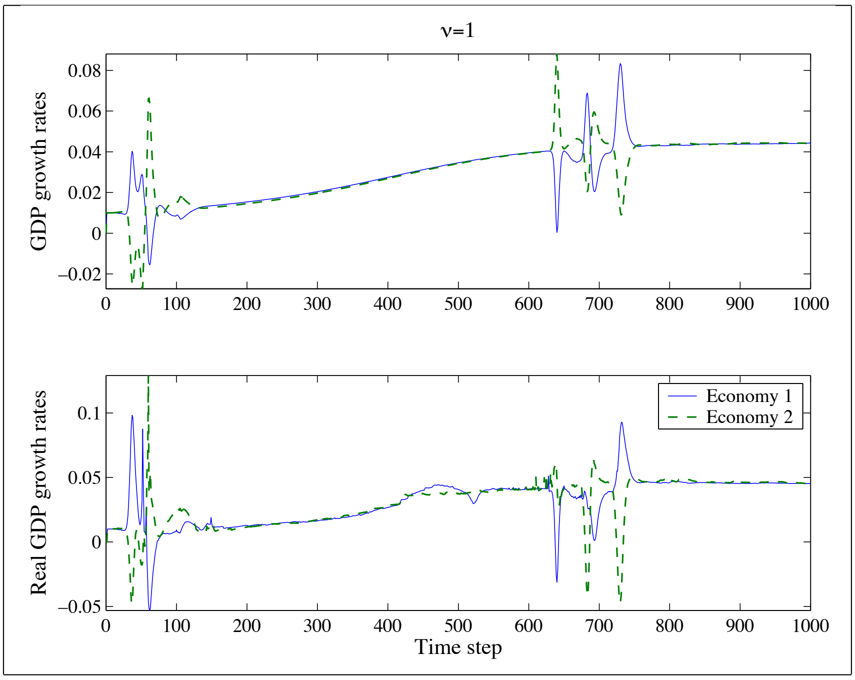

Figure 7.9: GDP growth rates (example run) $b_{\bar{j}j} = 0{,}5$, Std dev.$(\theta) = 1{,}65$, $\nu = 1$.

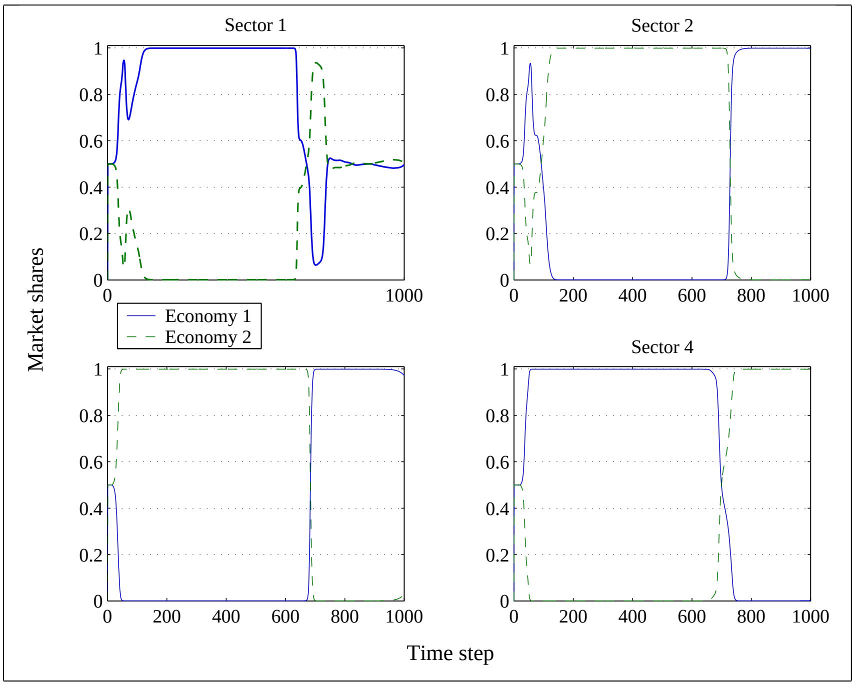

Figure 7.10: Aggregate market shares (ex.) $b_{\bar{j}j}$=0.5, Std dev.(θ) = 1.65, $\nu = 1$.

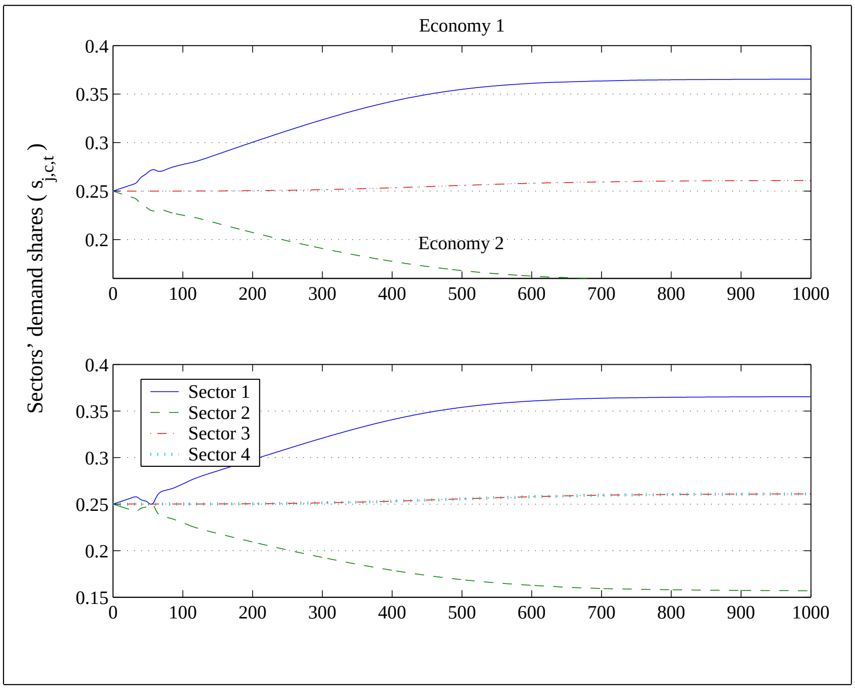

Figure 7.11: Sectors' demand shares (ex.) $b_{\bar{j}j} = 0.5$, Std dev.$(\theta) = 1.65$, $\nu = 1$.

shares (Figure 7.10). The latter are only due to the emergence of technological shocks at the micro-level. These also drastically modify the sectoral structure of the economies: These shocks, first, leads to the de-specialisation of the Economy 1, significantly active in three of the four sectors. Second, these reverses the leaderships in every sectors.

7.2.2 Demand Shocks, structural change and growth rates differences

The results found with the two first sets of simulation results showed that the introduction of satiation levels in sectoral demand drastically modified the effects of demand characteristics on macro-dynamics. Hence, these effects gradually disappear while the economies reach their long run sectoral structures. The sectoral structure of the economies is directly defined by the long-run demand shares (or the value of the 'satiation' levels).

The aim of this last simulation sets is to highlight the effect that structural change can play on these macro-dynamics. We generate structural change through the introduction of stochastic changes in the long-run demand shares. We control these demand shocks with the help of two parameters:

- $Freq$ defines the frequency of the demand shocks. It formally sets the simulations steps at which the demand shocks arise. Through the simulation we set this parameter as equal to 100, 250, 500 and 750 corresponding respectively to shocks arising every 100, 250, 500 and 750 steps.

- *StdDev* defines the amplitude of the demand shocks. It formally corresponds to the standard deviation of the Normal distribution from which the shocks are drawn.

Formally the demand shocks are introduced using the following procedure:

1. At the frequency defined by the parameter $Freq$, the algorithm randomly draw as sector among all the J sectors available in our artificial system. Every sector has an equal probability to be chosen.

2. For the chosen sector j, the algorithm then apply a random change on the parameter θ_j defining the long-run demand share of the sector j:

$$\theta'_j = \theta_j + \varepsilon$$

$$\varepsilon \sim N(0; StdDev)$$

3. The new θ'_j then affects each sectors long-run demand share so that:

$$\bar{s}'_j = \frac{\theta'_j}{\theta'_j + \sum_{\bar{j}} \theta_{\bar{j}}} \text{ for the chosen sector,}$$

$$\bar{s}'_{\bar{j}} = \frac{\theta_{\bar{j}}}{\theta'_j + \sum_{\bar{j}} \theta_{\bar{j}}} \text{ for the other sectors.}$$

We therefore introduce structural change through the stochastic change in the value of the parameter θ_j for one of the sectors. Through changes in the parameters defining these shocks we test the effect of changes in the amplitude and frequency of structural change on the macro-dynamics. As in the previous section, we analyse this effect for the two settings of ν respectively neutralising or favouring sectoral specialisation.

We first present the results of the simulation run when introducing the demand shocks but neutralising the specialisation mechanisms ($\nu = 0$). As shown by Figure 7.12, changes in the amplitude and frequency of the demand shocks slightly modifies the specialisation level of the economies. In any case it does not really lead the economies to specialise. In this sense,

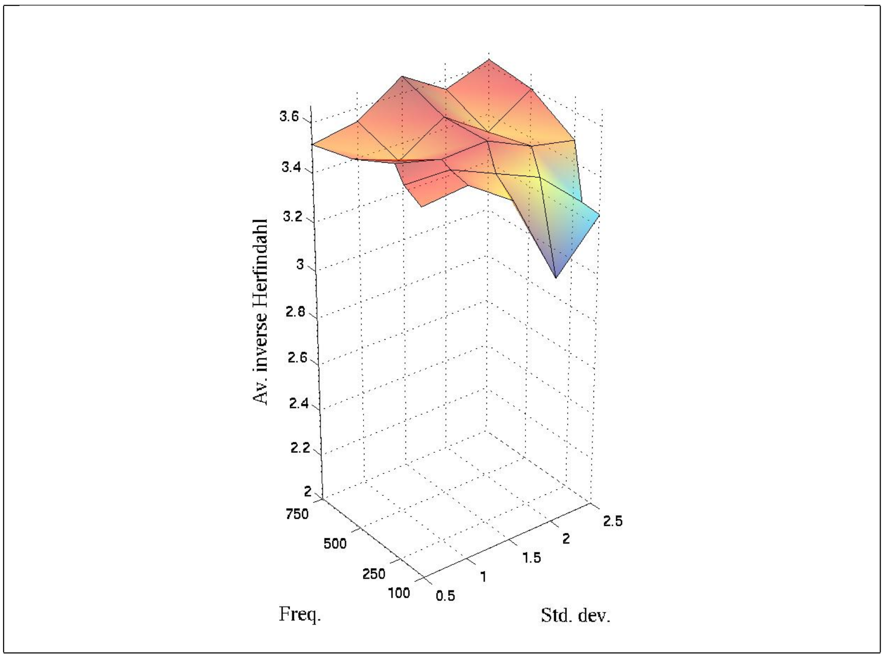

Figure 7.12: Average inverse Herfindahl and demand shocks (Freq. vs. Std Dev.) , $\nu = 0$.

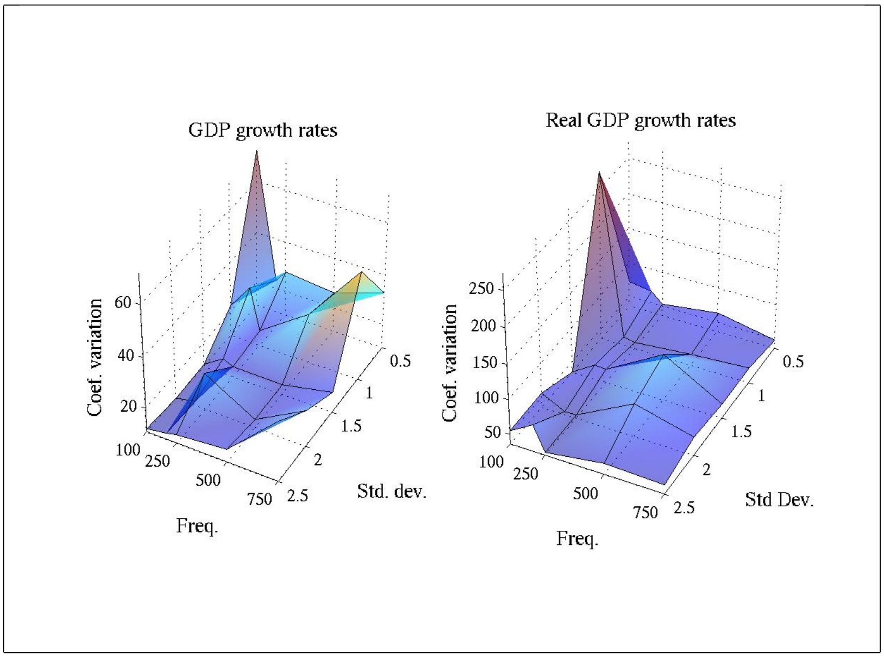

Figure 7.13: Coefficient of variation in GDP growth rates and demand shocks (Freq. vs. Std Dev.) , $\nu = 0$.

introducing demand shocks does not modify the result previously found on sectoral specialisation (see Result 18).

The introduction of demand shocks affects growth rates differences. The changes in the frequency and amplitude of the shocks, however, presents a counterintuitive pattern. In particular, increasing the frequency and amplitude of the shocks seems to affect negatively the growth rates differences (Figure 7.13).

This counterintuitive finding con be explained as follows: Specialisation mechanisms are neutralised. The differences in θ, and therefore the demand shocks themselves do not directly affect growth rates differences. Nevertheless these factors increase the amplitude of the effect of the technological shocks on growth differentials. We can then sum-up the results of this third set of simulations as follows:

Result 20 *When specialisation mechanisms are neutralised, the introduction of demand shocks do not generate growth rates differences. The growth differential is due to the micro-level technological shocks. The differences in demand shares due to the technological shocks shape the amplitude of the differences in growth rates consequent to the technological shocks.*

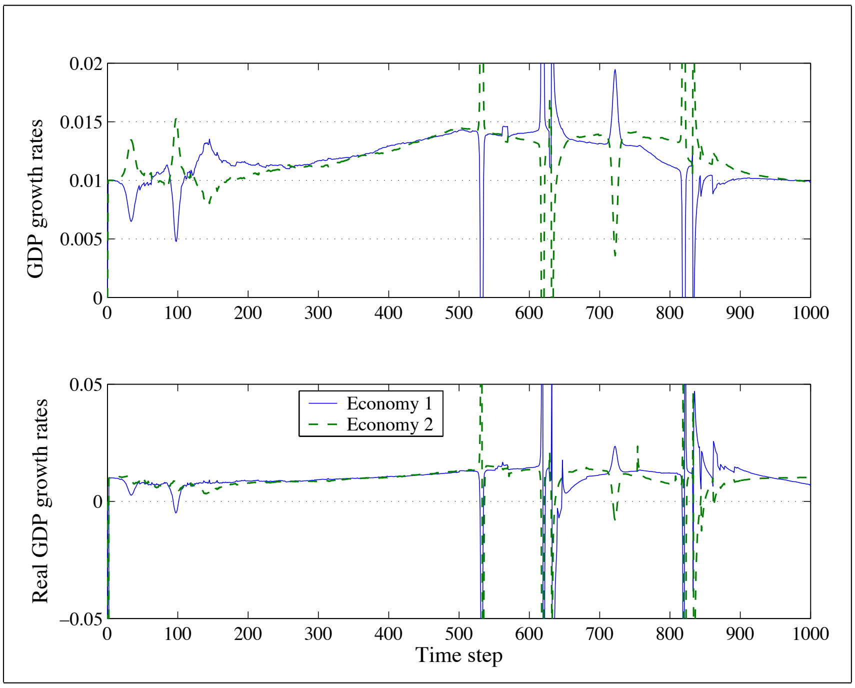

Figure 7.14: GDP growth rates (example run) Freq. $= 250$, Std dev. $= 1$, $\nu = 0$.

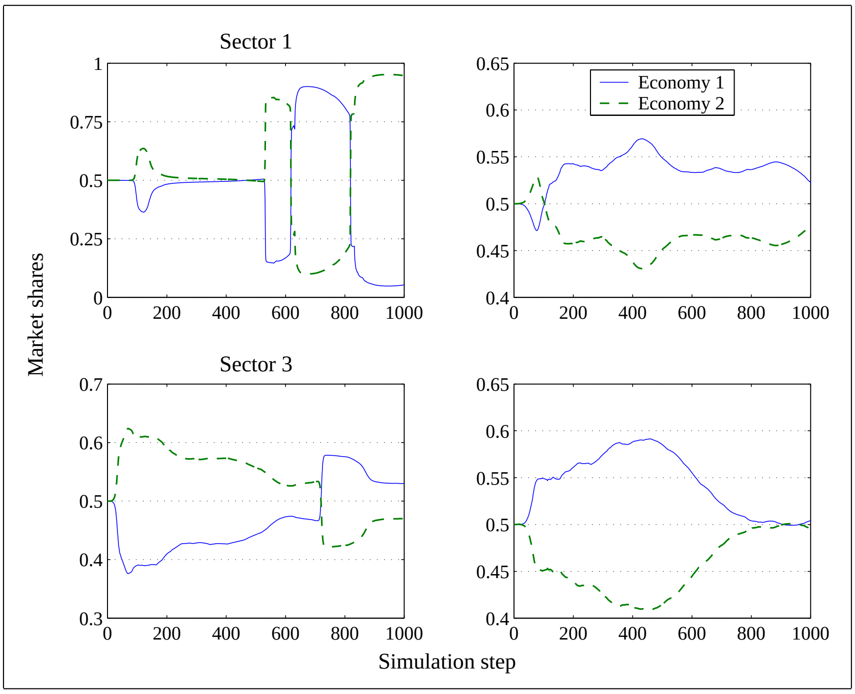

Figure 7.15: Aggregate market shares (ex) Freq. = 250, Std dev. = 1, $\nu = 0$.

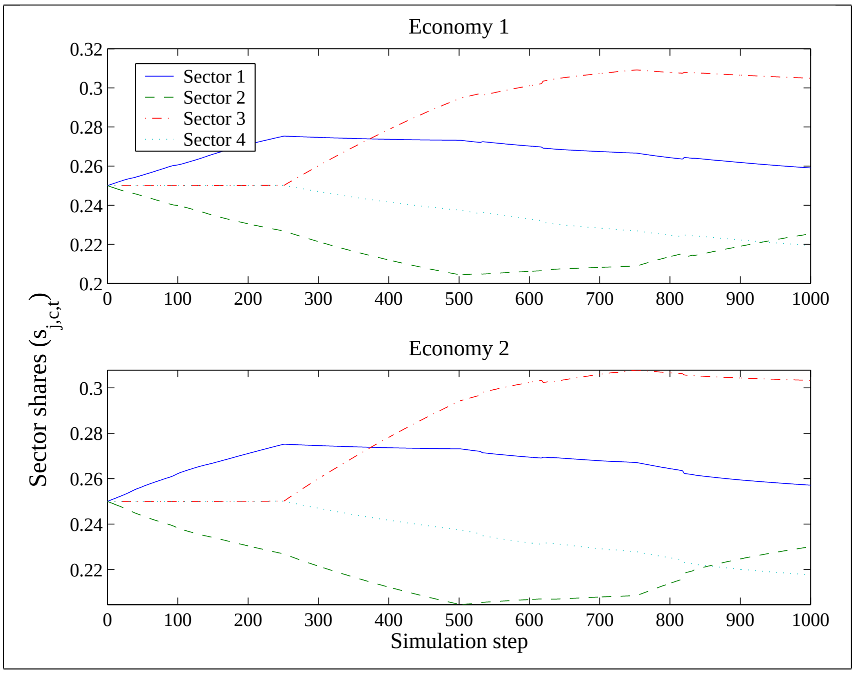

Figure 7.16: Sectors' demand shares (ex) Freq. = 250, Std dev. = 1, $\nu = 0$.

This can be illustrated by the example of simulation run presented by the Figures 7.14, 7.15 and 7.16. On the one hand, the changes in market shares (Figure 7.15) correspond to the emergence of micro-level technological shocks. These exactly corresponds to the sudden increases in the differences in GDP growth rates (Figure 7.14). On the other hand, demand shocks modify the sectors' demand share (Figure 7.16). These changes affect the intensity of the growth differential following the technological shocks (Figure 7.14).

For the last set of simulation presented in this chapter, we consider the effect of demand shocks when the mechanisms leading to specialisation are active. We previously found that specialisation and the consequent growth differential were only transitory. This was due to the fact that specialisation gains were gradually disappear when reaching the sector demands' 'satiation' levels.

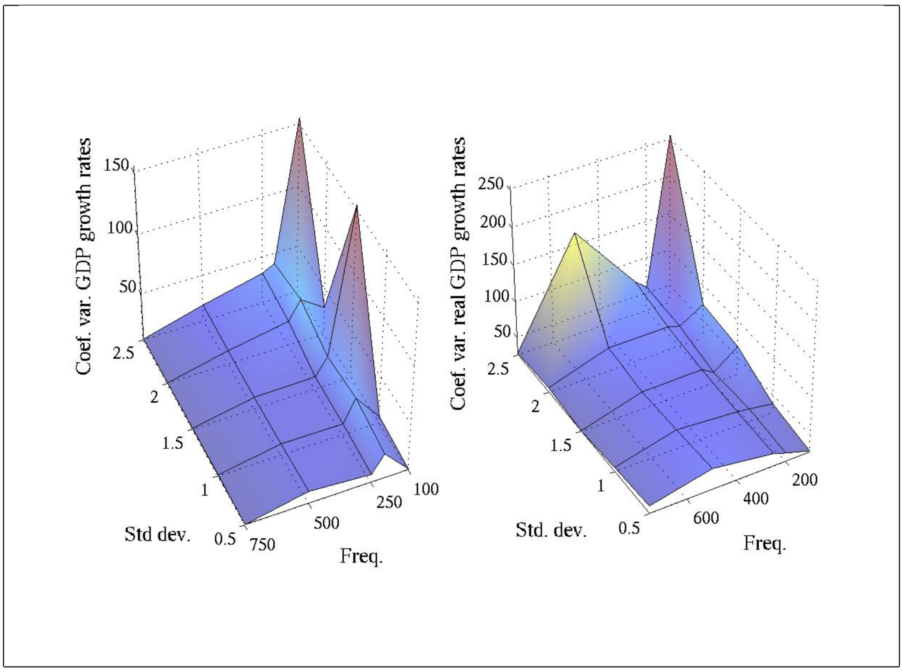

Figure 7.17: Coefficient of variation in GDP growth rates and demand shocks (Freq. vs. Std Dev.) , $\nu = 1$.

The introduction of demand shocks clearly affects growth rates differences. Modifying the characteristics of these demand shocks clearly affects the growth differentials. Figure 7.17 presents the coefficient of variation in GDP growth rates among economies for various settings of the frequency and the standard deviation of the demand shocks. First, increasing the amplitude of demand shocks amplifies the growth differential. Second, the effect linked to the amplitude of the shocks is itself reinforced when increasing the frequency of the shocks.

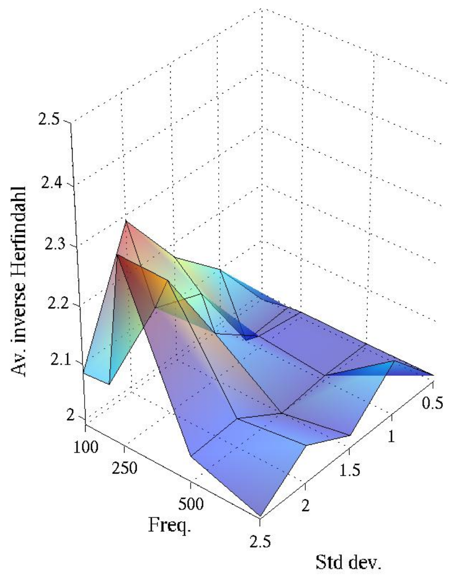

Figure 7.18: Average inverse Herfindahl and demand shocks (Freq. vs. Std Dev.) , $\nu = 1$.

The introduction of demand shocks seems also to influence the specialisation levels of the economies. We found previously that the loss of specialisation gains, once the 'satiation' levels were reached, led the economies to a de-specialisation process. The introduction of demand shocks seems to reduce this process, as shown by Figure 7.18. This de-specialisation process, however, emerges when the demand shocks are important (high values of $StdDev$) and frequent (low values of $Freq$).

The results coming out from this set of simulations can be summarised as follows:

Result 21 *When specialisation can occur, the introduction of demand shocks favours the emergence and persistence of growth rates differences. The more frequent and more important are these shocks the higher the growth differential. The existence of demand shocks prevents the emergence of the de-specialisation process consequent to the loss of specialisation gains. The more frequent and important shocks, can limit specialisation, limiting these gains.*

These results can be explained as follows: We showed in the previous section that the introduction of 'satiation' levels reduced the impact of specialisation mechanisms on growth differential. The differences in income elasticities among sectors disappeared, when the demand shares reached their long-run values. This induced the loss of the specialisation gains and of their impact on growth differentials.

The introduction of a demand shock mechanically modifies the entire sectoral structure. This restarts the entire income elasticity dynamics which generate new specialisation gains, therefore the self-sustained specialisation process and the consequent growth differential.

The amplitude of the shock defines, first, the amplitude of the specialisation gains. The demand shocks re-define the sectoral structure of the economy and therefore the differences in demand characteristics among sector. Second, the larger is the amplitude of the shock, the larger the distance between the actual and the long-run demand shares. The larger this distance is, the longer the process of structural change. The frequency of the demand shocks therefore favours the persistence of these structural change. If the demand shocks are too frequent, this can however limits the impact of specialisation. Shocks then arise before the economies fully specialise and gain from this.

The simulation conducted in this chapter highlighted two major results: First, the introduction of 'satiation' levels in the sectors demand drastically modified the results found in the previous chapter. The demand characteristics shape the sectoral structure of the economies. These when combined to specialisation explains the emergence of growth differentials. However, the impact of growth rates differences gradually disappear, when the economies reach their long run structure. The economies therefore gradually de-specialise.

Second, the introduction of demand shocks allows for the persistence of structural change. The gains of specialisation and its impact on growth rates differences is then favoured by the constancy of structural change. This results is linked to the fact that the mechanisms driving structural change also preserves the differences in income elasticity among sectors.

Table 7.1 sumarises the results found trough the simulations.

7.3 Concluding remarks

This chapter has aimed to complete the analysis of the determinants of growth rates differences among economies initiated in the two previous chap-

Table 7.1: Main Simulation Results

<table>
<tr><td rowspan="2"></td><td colspan="2">Demand characteristics</td><td colspan="2">Demand shocks</td></tr>
<tr><td>$\nearrow b$</td><td>$\nearrow StdDev(\theta_j)$</td><td>$\nearrow Freq.$</td><td>$\nearrow StdDev$</td></tr>
<tr><td rowspan="2">$\nu = 0$</td><td colspan="2">-no specialisation</td><td colspan="2" rowspan="2">-no specialisation
-reduce growth
rates differences</td></tr>
<tr><td>-no effect</td><td>-increase growth
differential</td></tr>
<tr><td rowspan="2">$\nu = 1$</td><td colspan="2" rowspan="2">-transitory specialisation

-transitory growth differences</td><td>-if too high limits
specialisation</td><td>-sustains
specialisation</td></tr>
<tr><td colspan="2">-sustains growth differences</td></tr>
</table>

ters. We have developed a modified version of the multisectoral growth model presented in Chapter 6.

First we released the balance of payment constraint. This first modification did not exhibit a clear effect on the macro-dynamics. This first point might, however, deserves a deeper analysis in the future.

Second, we release the assumption of the constancy of sectors' income elasticity. In this sense, we introduced 'satiation' levels in sectors demand. We choose to focus on the effects of this second modification. The latter drastically modified the results found in Chapter 6. The simulation conducted in this chapter exhibited the following results:

First, the characteristics of sectors' demand, and especially the 'satiation' levels that shape the sectoral structure of the economy, affect significantly growth rates differences, mainly when specialisation occurs. This effect and the self-sustained nature of specialisation as found in Chapter 6, is here only transitory. This is due to the dynamics of income elasticity. Hence, as GDP grows, demand shares reach their long run values. Each income elasticity gradually tend to one as the 'satiation' levels are reached. The specialisation gains as well as the effect of specialisation on GDP dynamics rely on differences in income elasticity. As these disappear when the satiation levels are reached, these effects also gradually disappear.

Second, simulation shows that the persistence of demand shocks, generating structural change, tend to sustain the existence of productivity gains and differences in income elasticity. Persistent structural changes prevent the economies to reach the sectors' demand satiation levels. These demand shocks are randomly generated in this model.

The continuation of this work might require to investigate the sources of these structural change. These possible sources might be rooted in the constant introduction of new production sectors, as in Verspagen and Werker

(2003) or Saviotti (2001) and Saviotti and Pyka (2004), or in the introduction of intermediate demand by firms, subject to micro-level technological shocks as in Lorentz and Savona (2005).

Simulation settings

Table 7.2: Key parameters settings

	Sector 1	Sector 2	Sector 3	Sector 4
ν	0	0	0	0
ν	1	1	1	1
θ_j	5	5	5	5
θ_j	6	4	5	5
θ_j	7	3	5	5
θ_j	8	2	5	5
θ_j	9	1	5	5
$b_{\bar{j}j}$	0	0	0	0
$b_{\bar{j}j}$	0.25	0.25	0.25	0.25
$b_{\bar{j}j}$	0.5	0.5	0.5	0.5
$b_{\bar{j}j}$	0.75	0.75	0.75	0.75
$b_{\bar{j}j}$	1	1	1	1
$StdDev$	0.5	0.5	0.5	0.5
$StdDev$	1	1	1	1
$StdDev$	1.5	1.5	1.5	1.5
$StdDev$	2	2	2	2
$StdDev$	2.5	2.5	2.5	2.5
$Freq$	100			
$Freq$	250			
$Freq$	500			
$Freq$	750			

Table 7.3: Other parameters and initial conditions

	Sector 1	Sector 2	Sector 3	Sector 4
ϕ	1	1	1	1
μ_j	1	1	1	1
ρ_j	0.4	0.4	0.4	0.4
ι_j	0.4	0.4	0.4	0.4
σ_j	0.1	0.1	0.1	0.1
χ_j	0.75	0.75	0.75	0.75
$\bar{z}_j$	0.0001	0.0001	0.0001	0.0001
$s_{j,c,t-1}$	0.25	0.25	0.25	0.25
$w_{j,c,t-1}$	1	1	1	1
$z_{i,j,c,t-1}$	0.05	0.05	0.05	0.05
$A_{i,j,c,t-1}$	1	1	1	1
$I_{i,j,t-1}$	1	1	1	1
$a_{i,j,t-1}$	1	1	1	1

	Economy 1	Economy 2
β	0.001	0.001
$Y_{c,t-1}$	100	100
$e_{c,t-1}$	1	1

Summary of the Results

The aim of this third part was to propose a formal framework for the analysis of the determinants of growth rates differentials. We choose to base the analysis on the combination of a Post-Keynesian macro-frame inspired by the cumulative causation literature and an evolutionary micro-founded process of technological change. We presented three models based on this combination. The mains findings obtained with these models can be summarised as follows.

Chapter 5 presents a baseline one-sector model where the macro-frame is derived from the balance of payment constraint, as in the cumulative causation literature (Dixon and Thirlwall (1975) and Thrilwall (1979)). The micro-dynamics develops around a simple evolutionary representation of technical change dynamics at the level of firms. The macro-frame acts as a macro-constraint on the micro-dynamics. The micro-dynamics affect themselves the evolution of the macro-frame. The simulation realised with this model show the emergence of three distinct regimes:

- The model generates a regime of sustained growth rate differences, which emerges with the introduction of heterogeneity in income elasticities. This regime does not necessary imply significant differences in technologies. The growth rate differential relies on the existence of differences in income elasticity of exports and/or imports among economies

- The second regime presents transitory phases of divergence. This pattern emerges with the introduction of heterogeneity in technological opportunities. Its transitory nature is related to the specific settings of the wage dynamics. The differences in growth generated by the uneven technological shocks gradually disappear as the wage dynamics absorb the uneven technological dynamics.

- The third regime shows a destructive divergence pattern, emerging when wage dynamics do not absorb at all technological shocks. In this regime the best firms and economy dominate the market. The lagging economies and firms gradually disappear. In this case growth rate difference increase over time until the collapse of the lagging economies. This regime therefore describes the traditional virtuous vs. vicious circles dichotomy found in the cumulative causation literature.

Chapter 6 presents a multi-sectoral extension to the baseline model. The macro-frame is again derived from the balance of payment constraint. The macro-dynamics is here affected by the sectoral structure of the economies and its changes. The model is used to consider the relationship between specialisation patterns and growth rates differences. The simulations conducted in Chapter 6 show the emergence of two main regimes:

- Uneven technical change among firms and sectors, reinforced by the cumulative nature of productivity gains, is one of the major forces driving specialisation. These forces also generate differences in GDP growth rates, but these are only transitory. Wages and market dynamics gradually absorb the effect of technical change on growth differentials.

- Specialisation mechanisms might lead to permanent growth rates differences if there exists significant differences in income elasticity among sectors. These differences in income elasticity generate differences in the resources available for investments, favouring productivity gains only in few sectors. In this case specialisation is self-reinforcing and growth rates differentials become permanent.

Chapter 7 slightly modifies the multi-sectoral model developed in Chapter 6. We introduced satiation levels to sectors' demand. These drastically modify the outcome of the simulations:

- Specialisation coupled with differences in demand characteristics affects directly growth differentials but this effect gradually fades away. In the long run as the economies reach their long-run structure, once the sectors' demand has reached the satiation levels, differences in income elasticity disappear. The latter implies that specialisation gains disappear.

- Introducing shocks in demand characteristics, we generate structural change. The persistence of the shocks prevents the economies to reach the satiation levels, and therefore growth differences persist.

The main outcome of these models has been to highlight the key role played by the macro-constraints in shaping both macro and technology dynamics. First, macro-constraints shape macro-dynamics through the dynamics of aggregate demand. Second, micro-dynamics requires some catalysers to affect macro-dynamics. This role is mainly played by wages dynamics that constitutes one of the macro-constraints.

Part IV

Conclusions

Chapter 8

Summary and Conclusions

Understanding why growth rates differ among economies is an age-old issue in economics. The developments of the “New Growth Theory” (NGT), since the 90s, brought this issue back at stake in the economic debate. As a matter of fact, NGT has been preceded or contemporary to a long tradition of research, which proposed some alternative explanations to the persistence of phenomena such as growth rate divergence among countries or regions.

Among these potential alternatives, the Neo-Schumpeterian, or Evolutionary approach, considers economic growth as being technology driven. Growth relies on the creation and diffusion of new and more efficient technologies. These technology dynamics are intrinsically uneven and uncertain, but also history dependant. Moreover these are by nature micro-processes. All the macro-dynamics are directly derived from past and present micro-dynamics. Therefore, GDP growth rate differences are directly linked to the micro-level ability of the economies to generate and/or capture new or more efficient technologies. Should we then consider that technology explains everything?

A second alternative to the NGT presents a more embracing answer. The Post-Keynesian approach also acknowledges the key role played by technology dynamics. However technical change is seen as a component of a complex set of causal relationships generating economic growth. Kaldor (1966) describes economic growth as being driven by a set of “cumulative causation”. Economic growth is driven by aggregate demand, itself driven by external demand fostered by a multiplier effect. External demand is in-turn driven by foreign income and the relative competitiveness of the economy, linked to its technology. Therefore, technical change affects growth through the demand dynamics, and is itself linked to the existence of static and dynamic increasing returns. These later link the growth of demand to technical change. The combination of these two sets of processes generates the 'cumulative causation' mechanisms sustaining growth. Therefore, important macro-feedbacks affecting technical change are at work and matter for understanding growth rates differences.

Despite the fact that the alternatives to the NGT are usually considered too heterogeneous to be built into an integrated and coherent framework, they actually have some common features, which could justify a comprehensive complementarity, as discussed in Chapter 2. In particular, Kaldor's cumulative causation provides Schumpeterians with a more embracing macroeconomic framework able to capture the macro-constraints affecting microdynamics, while the Evolutionary/Schumpeterian approach provides Kaldorians with a micro-founded analysis of the dynamics underlying the process of technological change. We aimed to propose a formal framework integrating these two streams of literature.

The second part of our thesis (Chapters 3 and 4) focused on productivity dynamics and the analysis of increasing returns through the Kaldor-Verdoorn Law. Post-Keynesian and Schumpeterian approaches to growth mechanisms share above all the idea that technical change, through productivity gains is one of the key processes generating long-run macro-dynamics. For both of them technical change relies on the existence of increasing returns, but their vision diverge in the formal representation of these increasing returns. This second part aimed to bridge the macro-representation of increasing returns proposed by the Kaldorians *via* the Kaldor-Verdoorn Law to the micro-founded approach proposed by the Schumpeterians.

Chapter 3 proposed to test whether the Law still holds. The use of the Kaldor-Verdoorn Law allows us to avoid the abuse of the micro-level assumptions in the empirical analysis. However, the relevance of the law has been questioned into the literature; first due to the arising of new production forms, and new sectors of activity after the 70's crisis; second due to its sensitiveness to the sample of country used.

We first estimated the Law at the macro-economic level using three different samples of countries: Kaldor (1966) sample of 12 countries, the pre-1974 OECD members sample of countries, and a third sample adding to the previous one a selected number of Eastern European, Latin American and South East Asian countries. We used these samples to estimate the Law for five decades. When the estimation is restricted to the sample of countries used by Kaldor (1966), the law does not hold any more after 1970. This result can be seen as in continuity with the results found by Boyer and Petit (1981) for the 1970s, supporting their claim that the changes in both production and demand structures led the increasing returns to disappear. Estimated over the extended samples, the results drastically modify. The law is verified after 1980. Two possible explanations can be found to this result. The first in line with Rowthorn (1975), states that there could be biases due to outliers. The second relies on the division of labour and structural change occurring in the most advanced economies and which have affected the peripheral ones. Increasing returns being dependent on the structure of the economies, we could infer that these changes explain that the sources of increasing returns are from 1970 onwards rather found in the peripheral countries.

In a second phase, we estimated the Kaldor-Verdoorn Law for 56 sectors for the two last decades. These estimations show that the law holds significantly, for the two periods and the major part of the sectors, including the non-manufacturing sectors. The empirical results, moreover, show a tendency towards a higher heterogeneity in the levels and significance of the estimated parameters of the law for the last period. This heterogeneity is however not linked to the traditional distinction between manufacturing and non-manufacturing sectors as considered by Kaldor (1966). Finally, the estimated values of the parameters of the law at the aggregate level decreased significantly. This latter seems to correspond to changes occurring in a limited number of sectors.

These estimations, however, only provided evidences on the existence of increasing returns, at the macro as well as the sectoral level. The use of the Kaldor-Verdoorn Law as such does not offer any indications on the sources of these increasing returns. Chapter 4 has developed a simple micro-founded model of technological change inspired by the evolutionary literature. We reverted to this model to identify some sources of the increasing returns. In this respect, we analyse the effects of changes in various micro-characteristics of the model on the estimates of the Law using the data generated with the simulation model. The simulations showed, first, that a Kaldor-Verdoorn Law emerges as an aggregated property of these micro dynamics. The analysis also highlighted that some of the micro-characteristics affect significantly the value, significance and robustness of the estimated coefficient of the Law. On the one hand, increasing the amplitude of the technological shocks and the strength of the selection mechanisms, increased the values but decreases the significance of the coefficient, and the robustness of the Law. On the other hand, augmenting the resources devoted to R&D, increasing the frequency of the shocks, affected positively the value, significance and robustness of the estimated coefficients.

The third part of the thesis (Chapters 5, 6 and 7) presented three formal models combining Kaldorian and Evolutionary precepts. Unlike the few existing attempts to be found in the literature (Chapter 2), the models developed draw on explicitly evolutionary micro-founded technical change included into a macro-economic framework inspired by the cumulative causation models. The macro-components of the models act on the micro-dynamics as a set of constraints. These macro-constraints are themselves affected by the micro-dynamics. In this sense, we included in our models a set of feedback mechanisms from macro-to-micro but also from micro-to-macro, around the evolutionary micro-dynamics.

Chapter 5 presented a baseline one-sector model where the macro-frame is derived from the balance of payment constraint, as in the cumulative causation literature (Dixon and Thirlwall (1975) and Thrilwall (1979)). The micro-dynamics are generated by a simple evolutionary representation of technical change dynamics at the level of firms, as developed in Chapter 4. The simulation realised with this model showed the emergence of three distinct regimes: The model generated a regime of sustained growth rate differences. The growth rate differential relies on the existence of differences in income elasticity of exports and/or imports among economies, without implying significant differences in technologies. The second regime presented transitory phases of divergence. The differences in growth generated by the uneven technological shocks gradually disappear as the wage dynamics absorb the uneven technological dynamics. The third regime showed a destructive divergence pattern, emerging when wage dynamics do not absorb at all technological shocks. This regime describes the traditional virtuous vs. vicious circles dichotomy found in the cumulative causation literature.

Chapter 6 presented a multi-sectoral extension to the baseline model. The macro-dynamics are affected by the sectoral structure of the economies and its changes. The chapter considered the relationship between specialisation patterns and growth rates differences. The simulations showed the following results: Uneven technical change among firms and sectors, reinforced by the cumulative nature of productivity gains, is one of the major forces driving specialisation. These forces also generate differences in GDP growth rates, but these are only transitory. Wages and market dynamics gradually absorb the effect of technical change on growth differentials. If there exists significant differences in income elasticity among sectors, these specialisation mechanisms might lead to permanent growth rates differences. In this case specialisation is self-sustained, generating the resources to foster its mechanisms, and growth rates differentials become permanent.

Chapter 7 slightly modified the multi-sectoral model, introducing satiation levels to sectors' demand. Again the structure of the economies mattered in the growth process but the changes introduced drastically modify the results of the simulations: Specialisation coupled with differences in demand characteristics affects directly growth differentials but this effect gradually fades away. In the long run as the economies reach their long-run structure, once the sectors' demand has reached the satiation levels, differences in income elasticity disappear, then specialisation gains disappear. Introducing shocks in demand characteristics, we generate structural change. The persistence of the shocks prevents the economies to reach the satiation levels, and therefore growth differences persist.

Reverting to these models has highlighted the key role played by the macro-constraints in shaping both macro and technology dynamics. First the aggregate demand dynamics constraints growth and growth differentials. This affects the resources allocated to investments and therefore affects technical change. There exists therefore an important macro-to-micro feedback mechanism. Second, micro-dynamics relies on two macro-mechanisms, namely market selection and wage dynamics to affect growth and the growth differential. Macro-constraints are therefore required for the functioning of the micro-to-macro feedback.

Moreover, contrary to the Harrod-Domar framework, our framework does not oppose demand and technology dynamics in shaping the growth process. These two components rather appear complementary in defining the growth mechanisms and explaining growth differentials among economies. Along the simulations, demand dynamics appeared as defining the broad macro and meso growth trends and their changes. Technology dynamics on the other side defines rather the fluctuations and specialisation patterns within this broad growth trends. Hence, via the selection mechanisms, technology dynamics helps the allocation among firms and economies of the resources provided by the extension of demand.

Understanding why growth rates differ among economies, requires therefore not only to account for demand or technological determinants, but to take also into account the whole set of feedback mechanisms that links these determinants. In our framework these mechanisms are mainly found among the macro-constraints. Among these, wage dynamics, selection mechanisms and/or the structure of the aggregate demand and its changes play crucial role in understanding the growth differential. These factors, however remain, unexplained in our models, opening a wide potential for future developments. We might more particularly stress the micro-foundations of the labour market mechanisms underlying the wage dynamics, the micro-foundations of demand dynamics defining the structure and the changes in the structure of final and intermediate demand or the market mechanisms underlying the selection mechanisms.

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Appendix A

Data-Sets Used In Chapter 3

This appendix presents the data used for the estimations of the Kaldor-Verdoorn Law realised along the Chapter 3. The Tables A.1, A.2, A.3, A.4 and A.5 present for all the considered countries and periods the GDP, labour productivity, and employment growth rates. The computation of these data is ours and based on the 2004 "Groningen Growth & Development Center & The Conference Board, Total Economy Database".

The tables A.6 and A.7 present the growth rates in GDP, Employment and productivity for the entire industries of the presented countries for respectively the periods 1980-1990 and 1990-2001. Tables A.8, A.9, A.10, A.11, A.12, A.13, A.14 and A.15 present respectively the detail of sectors GDP and employment growth rates, for all the considered countries for the two periodes 1980-1990 and 1990-2001. The computation are ours based on the October 2003 "Groningen Growth & Development Center, 60 Industry Database".

These two databases are available at http://www.ggdc.net.

Table A.1: Growth rates for the period 1950 - 1960

	GDP	Productivity	Employment
Australia	0.460444529664605	0.315738552196761	0.144705977467845
Austria	0.774143184981754	0.77169880486418	0.00244438011757353
Belgium	0.338003791312948	0.33378659096348	0.00421720034946849
Canada	0.544221507300451	0.352625772008508	0.191595735291943
Denmark	0.399741202567808	0.416362952350633	-0.0166217497828245
Finland	0.611695544554455	0.486512475207355	0.125183069347101
France	0.558328163567007	0.694564057367833	-0.136235893800826
West Germany	1.13699515347334	0.961226129821615	0.175769023651729
Greece	0.807595689826139	0.714315379241069	0.0932803105850692
Ireland	0.198561706646074	0.438376132693304	-0.23981442604723
Italy	0.808651516966709	0.457914844018894	0.350736672947815
Japan	1.32560505978228	0.860626194261213	0.464978865521062
Luxembourg	0.333054568262597	0.266434171849656	0.066620396412941
Netherlands	0.55549299911877	0.504188547306248	0.0513044518125221
Norway	0.45714050899926	0.530559177336649	-0.0734186683373887
Portugal	0.523668064077293	0.722131397508027	-0.198463333430735
Spain	0.553217226779982	0.540839688462994	0.0123775383169877
Sweden	0.386643434249147	0.394106629655699	-0.00746319540655183
Switzerland	0.569921499971763	0.347489342779125	0.222432157192637
Turkey	0.753310668165492	0.856061458071316	-0.102750789905824
U.K.	0.303615433857728	0.221515532912373	0.0820999009453549
U.S.A	0.370007939921262	0.438112924565076	-0.0681049846438135
USSR	0.696501497347012	0.440514469453376	0.255987027893636
Hong Kong	1.07686691697956	-0.191440814859681	1.26830773183924

Table A.2: Growth rates for the period 1960 - 1970

	GDP	Productivity	Employment
Australia	0.702491274521603	0.362758325002993	0.33973294951861
Austria	0.582864170828165	1.11626216839143	-0.533397997563269
Belgium	0.604410496488851	1.04699895751265	-0.442588461023798
Canada	0.660488538514167	0.413608574350211	0.246879964163957
Denmark	0.521316317097475	0.78168916593006	-0.260372848832584
Finland	0.555873575455069	1.17221293542149	-0.616339359966426
France	0.713025666219156	0.644644543850248	0.0683811223689077
West Germany	0.531297248261264	0.715835159153964	-0.184537910892701
Greece	1.06822462376799	1.43520672820584	-0.366982104437847
Ireland	0.498489912616277	0.835420246590945	-0.336930333974668
Italy	0.701028962491094	0.924992471360633	-0.223963508869539
Japan	1.60874900670911	1.3080467952879	0.300702211421215
Luxembourg	0.404328732747804	0.698986517657098	-0.294657784909294
Netherlands	0.67346383689457	0.560900241245032	0.112563595649538
Norway	0.496239894717052	0.697040877300376	-0.200800982583324
Portugal	0.863650443687251	1.58863834057259	-0.724987896885336
Spain	1.19858117080866	1.58220475405336	-0.383623583244699
Sweden	0.537188846337961	0.82535571681298	-0.288166870475019
Switzerland	0.555387681394027	0.550956806454795	0.00443087493923233
Turkey	0.799236885931648	0.895242062278231	-0.0960051763465832
U.K.	0.315340557241907	0.406325893296153	-0.0909853360542461
U.S.A	0.511668694699481	0.289902108343202	0.22176658635628
USSR	0.578869719115466	0.524553571428571	0.054316147686895
Argentina	0.509668397754219	0.518461537160043	-0.00879313940582338
Brazil	0.769519329318148	0.704318564353744	0.0652007649644037
Chili	0.543899386064255	0.299897008163093	0.244002377901162
Colombia	0.671906755797155	0.433120257546676	0.238786498250479
Mexico	0.876148785914675	0.671462358473499	0.204686427441177
Venezuela	0.611494300922442	0.105142672038404	0.506351628884039
Hong Kong	1.34479987947572	0.233033743297246	1.11176613617847
Singapore	1.46921524097906	1.19672568474449	0.272489556234562
Taiwan	1.68640350877193	1.43519784701939	0.251205661752537

Table A.3: Growth rates for the period 1970 - 1980

	GDP	Productivity	Employment
Australia	0.379837538398262	0.171938200710372	0.20789933768789
Austria	0.390874198712581	0.284721342769862	0.106152855942719
Belgium	0.358836289641404	0.330195622161541	0.0286406674798632
Canada	0.49961023920177	0.0892563736086007	0.410353865593169
Denmark	0.225790159018269	0.0852774875228177	0.140512671495452
Finland	0.401379697139652	0.0888377123624844	0.312541984777168
France	0.348128961863918	0.446168584795005	-0.0980396229310867
West Germany	0.28870458135861	0.413757329707826	-0.125052748349217
Greece	0.530064983864551	0.237923892886835	0.292141090977716
Ireland	0.587122433623562	0.414159963622233	0.172962470001329
Italy	0.413360927199492	0.430392730675285	-0.0170318034757935
Japan	0.535855433114585	0.450371494443742	0.085483938670843
Luxembourg	0.280545007817735	0.136610341675964	0.143934666141771
Netherlands	0.306008541346601	0.337640633446532	-0.0316320920999302
Norway	0.560809197713137	0.346590692214821	0.214218505498316
Portugal	0.550494236353504	0.0987044799523085	0.451789756401195
Spain	0.570781740688346	0.447384431049477	0.123397309638869
Sweden	0.207901087993149	0.135516844220638	0.0723842437725108
Switzerland	0.118059281736267	0.0899435675676201	0.0281157141686466
Turkey	0.608655596935472	0.279719376181093	0.328936220754379
U.K.	0.195120097859044	0.326008955092799	-0.130888857233755
U.S.A	0.368480956727518	0.139773264164756	0.228707692562761
USSR	0.253413757231763	0.0351390922401171	0.218274664991646
Argentina	0.26171358424239	0.05867692589157	0.20303665835082
Brazil	1.03387679597292	0.251923635385821	0.7819531605871
Chili	0.262894757161609	0.124032487710658	0.138862269450951
Colombia	0.67814408529709	0.141149939325922	0.536994145971168
Mexico	0.937812869266301	0.239536894803965	0.698275974462336
Venezuela	0.292636002438381	-0.167507514301917	0.460143516740298
Hong Kong	1.38248522230789	0.359108672372364	1.02337654993553
Singapore	1.34147463083133	0.274280150093304	1.06719448073803
South Korea	1.21646792763158	0.264283921820824	0.952184005810755
Taiwan	1.34129967776584	0.488801065111734	0.852498612654109

Table A.4: Growth rates for the period 1980 - 1990

	GDP	Productivity	Employment
Australia	0.35796316006767	0.116227561000974	0.241735599066696
Austria	0.277596101867897	0.189089616877153	0.0885064849907442
Belgium	0.222113084897583	0.26041096297296	-0.0382978780753769
Canada	0.284400836610242	0.101201971644744	0.183198864965498
Denmark	0.228279052736329	0.211115841809373	0.0171632109269562
Finland	0.303371098014546	0.312160470606063	-0.00878937259151669
France	0.261222347210625	0.306172093970714	-0.044949746760089
West Germany	0.279828230726199	0.301814866257373	-0.0219866355311744
Greece	0.19063572552701	0.166187878810224	0.0244478467167852
Ireland	0.417507863465653	0.47348356511801	-0.0559757016523565
Italy	0.252709681456797	0.207450171551153	0.0452595099056445
Japan	0.480543464027003	0.337905100705814	0.142638363321188
Luxembourg	0.60477287906358	0.402307162420219	0.202465716643362
Netherlands	0.258245197496223	0.220680127506685	0.0375650699895373
Norway	0.284032884007604	0.290213146552636	-0.00618026254503223
Portugal	0.384426823192937	0.23000275243212	0.154424070760816
Spain	0.388944584492594	0.356745777558719	0.0321988069338754
Sweden	0.213597747774058	0.113536685739517	0.100061062034541
Switzerland	0.210636096199843	0.110606994499711	0.100029101700133
Turkey	0.657629218892188	0.463152905855777	0.194476313036411
U.K.	0.296720855866651	0.231127197580581	0.0655936582860701
U.S.A	0.351461540040392	0.146837804589858	0.204623735450533
Hungary	-0.0705589119578253	0.155110793423874	-0.2256697053817
USSR	0.121611629874356	0.111032531824611	0.0105790980497453
Argentina	-0.0100998065707042	-0.11133473364994	0.101234927079236
Brazil	0.195690249151284	-0.0267764443492619	0.222466693500546
Chili	0.331599237872413	-0.025103191271297	0.35670242914371
Colombia	0.400466616368518	0.153546986217577	0.246919630150942
Mexico	0.169903175021149	-0.0828554289541534	0.252758603975303
Venezuela	0.13099520832872	-0.0656820916409847	0.196677299969705
Hong Kong	0.844299382702482	0.607919682596114	0.236379700106368
Singapore	0.955029284206295	0.458890064947739	0.496139219258556
South Korea	1.41393488959925	0.831106197221682	0.582828692377569
Taiwan	0.908919478904491	0.618089771230116	0.290829707674375

Table A.5: Growth rates for the period 1990 - 2000

	GDP	Productivity	Employment
Australia	0.443064409333177	0.242170802129623	0.200893607203555
Austria	0.24890755141954	0.269579811060795	-0.0206722596412547
Belgium	0.231737461646083	0.253731976961208	-0.0219945153151251
Canada	0.362809789543019	0.178182377090232	0.184627412452788
Denmark	0.261203910454597	0.205646580500482	0.0555573299541154
Finland	0.251192318365182	0.331365309293415	-0.0801729909282323
France	0.209767442423244	0.149713428292227	0.0600540141310164
All Germany	0.17069389018804	0.28036085231347	-0.10966696212543
Greece	0.266363057485107	0.177023280899313	0.089339776585794
Iceland	0.318248099084584	0.0826727128434264	0.235575386241158
Ireland	1.05088214101118	0.576968211316675	0.473913929694502
Italy	0.175094158495197	0.181462718221143	-0.00636855972594552
Japan	0.137919031019599	0.222520412710028	-0.0846013816904285
Luxembourg	0.64843041430018	0.221246342834985	0.427184071465195
Netherlands	0.325009593452051	0.107506389930441	0.21750320352161
New Zealand	0.355239600443826	0.102065429660766	0.25317417078306
Norway	0.429396070646056	0.312917999236837	0.116478071409218
Portugal	0.301193253196292	0.282705392060207	0.0184878611360848
Spain	0.302236348574611	0.0887652096210785	0.213471138953533
Sweden	0.230384478059752	0.232741547923199	-0.00235706986344697
Switzerland	0.099832014876388	0.106430699580348	-0.00659868470396008
Turkey	0.361725180923688	0.261012729180171	0.100712451743517
U.K.	0.289391334134216	0.274662504956512	0.0147288291777039
U.S.A	0.381246891978053	0.151038682916026	0.230208209062027
Czech Republic	0.0912882703759772	0.152407932011332	-0.0611196616353544
Estonia	-0.00898946063236206	0.11936936936937	-0.128358830001732
Hungary	0.170752298365582	0.342821782178218	-0.172069483812635
Latvia	-0.324487310050121	-0.233808290155441	-0.0906790198946802
Lithuania	-0.227752857762987	-0.182194616977226	-0.045558240785761
Poland	0.49048924429295	0.616727941176471	-0.126238696883521
Slovakia	0.20473656300624	0.415119363395225	-0.210382800388985
Slovenia	0.2750569476082	0.363423212192263	-0.0883662645840626
Argentina	0.388309464003102	0.1897162486344	0.198593215368702
Brazil	0.296209706132569	0.122119183230493	0.174090522902077
Chili	0.742137877609007	0.411902820597631	0.330235057011376
Colombia	0.274824020538644	0.0611777944175773	0.213646226121067
Mexico	0.374545634688601	0.0619879909677041	0.312557643720897
Venezuela	0.218805510812967	-0.122217531081656	0.341023041894623
Hong Kong	0.519066715875139	0.288994868880839	0.2300718469943
Singapore	0.992582437865794	0.477332139035835	0.515250298829959
South Korea	0.763440390951486	0.544633849120304	0.218806541831182
Taiwan	0.775355379039678	0.671297896871624	0.104057482168054
Cyprus	0.533099004100762	0.353476988670729	0.179622015430034
Malta	0.607122668174109	0.434149420378848	0.172973247795261

Table A.6: Total industry growth rates for the period 1980-1990

	Gross Product	Employment (hours)	Labour Productivity
Austria	0,285092455	-0,033289172	0,323683052
Belgium	0,241208644	-0,065700326	0,328019485
Denmark	0,193033281	-0,033561305	0,215333818
Finland	0,406017951	0,02071406	0,377974257
France	0,277983239	-0,059242431	0,352661653
Germany	0,26062392	0,022622522	0,23259592
Greece	0,200315294	0,059705117	0,132848055
Ireland	0,464915122	-0,057827425	0,553990255
Italy	0,263719907	0,026884756	0,229475562
Luxembourg	0,61851051	0,097714519	0,474278482
Netherlands	0,284672388	-0,001778873	0,270212223
Portugal	0,341059648	-0,022587867	0,371565131
Spain	0,336187373	-0,024711447	0,370022924
Sweden	0,292670623	0,093947283	0,170255473
United Kingdom	0,279740325	0,029154301	0,247955521
United States	0,344829759	0,183796545	0,135987552

Table A.7: Total industry growth rates for the period 1990-2001

	Gross Product	Employment (hours)	Labour Productivity
Austria	0,312109183	-0,033289172	0,394131985
Belgium	0,216137467	-0,037290779	0,263336921
Denmark	0,219652743	0,035870418	0,173661975
Finland	0,20936891	-0,098349961	0,340782493
France	0,173221993	0,010840922	0,15872565
Germany	0,255041653	-0,007156527	0,264181873
Greece	0,226889723	0,074615773	0,141756067
Ireland	1,284345367	0,293610229	0,765503012
Italy	0,165918258	0,003893831	0,156695666
Luxembourg	0,654595065	0,322459623	0,250970446
Netherlands	0,315051831	0,141746021	0,146752739
Portugal	0,285932447	-0,005140199	0,293002103
Spain	0,25810718	0,129501653	0,113804094
Sweden	0,199321626	-0,027395282	0,22664072
United Kingdom	0,289638134	-0,022550542	0,311427356
United States	0,368283682	0,164082248	0,175290556

Table A.8: Gross Product growth rates for the period 1980-1990 (I)

Sect	Austria	Belgium	Denmark	Finland	France	Germany	Greece	Ireland
1	0,17426637	0,2892249	0,5905800	0,0387940	0,14300311	0,20819780	0,03719168	0,20468562
2	0,17105039	0,25024648	-0,04439338	-0,0350606	0,25648631	0,30805683	-0,18721082	0,20468562
3	0,39773122	0,26041077	-0,36897546	0,13157969	-0,30804284	0,21011988	0,09277727	0,20468562
4	-0,39059584	-0,54219395	2,17294656	0,93840851	-0,19457118	-0,26796924	0,48223300	-0,54871968
5	0,26655075	0,2159284	0,08398208	0,242681	0,00883493	-0,00134506	0,28565528	1,06219225
6	-0,17025863	0,24067992	-0,02875583	-0,2149451	-0,30387665	-0,03244568	-0,32261830	0,12162067
7	-0,12826472	0,06830472	-0,13397157	-0,26290427	-0,27064811	-0,13455303	0,10228091	0,15503501
8	-0,13578054	-0,24442312	-0,27620538	-0,13357197	-0,27064776	-0,30408092	-0,05634589	-0,44864075
9	0,08702529	0,88485234	0,15546133	0,17348020	0,05837995	-0,10390565	-0,12105832	0,40330221
10	0,59026568	0,38249404	0,18008833	0,39773003	0,05837927	0,26759410	0,53346068	0,40573367
11	0,51626499	0,46660394	-0,11733164	0,60727157	0,23925001	0,13004181	0,29393205	0,44938030
12	-0,72834684	0,00266753	0,62466210	0,15028087	-0,83497421	-0,25711326	0,42995841	1,28584258
13	0,53218514	1,44975847	0,33678048	0,59942818	0,35181947	0,28925485	0,53336233	2,13523169
14	0,32182104	1,41646311	0,5041098	0,54552283	0,0916134	0,49788500	0,2216538	1,28036122
15	0,08705641	0,22805386	-0,26115641	0,44881055	0,23186721	-0,01174143	0,02836952	0,6637212
16	0,44642200	0,43607849	0,57864875	0,48282901	0,11870038	0,02301646	0,14579542	0,99729793
17	0,13809271	0,0050033	0,22073278	1,05887732	-0,16640937	0,17052748	-0,09468788	0,15887850
18	0,40718068	0,14485514	0,07356861	0,57312554	0,06703659	0,14683569	0,08803756	1,25635418
19	14,0080740	32,3165596	13,4499738	42,3749210	10,0434446	12,9553667	10,4664184	46,5419270
20	0,99708987	0,37214513	0,55444360	-0,06583225	0,52601676	0,45490927	0,40611310	5,43737517
21	0,46941771	0,01011512	0,14246147	0,62513573	0,12139766	0,35145375	0,03482628	3,73568100
22	7,65447065	4,69063203	5,54480452	15,1431929	5,54462800	6,45560389	4,78251039	25,5332921
23	6,90925392	4,1922169	4,93436467	13,5237890	4,12205736	5,83330628	4,31030771	23,3603701
24	3,21616480	1,77173615	2,17340206	5,78146007	1,53969571	2,64347422	1,83686369	11,9965884
25	0,48944033	0,29735567	0,49372589	2,28235464	0,02297211	0,2308466	0,06789239	1,64221045
26	0,58617711	0,38417907	0,59599184	0,84333240	0,0205963	0,01597211	0,1381801	1,81848183
27	0,06926304	0,66468971	-0,17806445	0,50512020	-0,00222927	0,27063972	-0,42826033	-0,20420565
28	-0,08845655	-0,00406950	-0,26888421	-0,23154196	0,20094449	-0,11931054	-0,11688956	-0,59788217
29	-0,26515005	-0,00406950	0,71853204	3,24628943	0,20094504	0,73747767	-0,11688956	
30	-0,26515005	-0,00406950	0,71853204	0,66932865	0,20094508	-0,09569073	-0,11688956	1,30364691
31	0,35778953	-0,08884775	0,27391974	0,28116857	0,13131321	-0,06546724	0,13921884	0,1874020
32	0,35147432	0,12985002	0,27772790	0,4110733	0,82626662	0,16294519	0,52731006	0,25243011
33	0,00431372	-0,04710401	0,03922046	0,34263784	0,08640428	-0,01041372	-0,03402720	-0,39412698
34	0,15107092	-0,02244774	-0,4364451	0,51445773	0,28488422	0,22409211	0,232708	0,4663980
35	0,55820433	0,03095616	0,28886647	0,36097246	0,61561317	0,17878754	0,232708	0,39981655
36	0,19781088	-0,1403493	0,00655076	0,56745431	0,45797714	0,18648321	0,232708	0,39245010
37	0,17566036	0,28759243	0,14533510	0,40128076	-0,06880313	0,10116991	0,232708	-0,02455863
38	0,25931662	0,19229640	0,02739758	0,29445847	0,38483140	0,24030426	0,44079485	-0,16243249
39	4,48766136	0,19229640	-0,14963548	-0,19263274	-0,44410364	-0,16450725	0,44079485	-0,40786524
40	1,45190807	0,19229640	0,12718191	1,44488960	0,67054225	0,42741860	0,44079485	-0,04197017
41	0,00549878	0,19229640	0,69499041	0,5367801	0,77769546	0,24030425	0,44079485	-0,00149912
42	0,5914051	0,30343067	0,55454162	1,01928253	1,01225950	0,59872122	0,44079485	-0,02469083
43	0,56906262	0,55857734	0,31524073	0,96581175	1,01708403	0,41598719	0,38458601	0,41174878
44	0,43472667	0,62035591	0,56896889	0,87327624	0,71652498	0,09853977	0,38458601	0,27660005
45	-0,13499986	0,53540882	1,43531017		0,71652428	0,41761310	0,38458601	0,3890237
46	0,48101597	0,60496630	0,0613167	0,4112110	0,33776550	0,50755409	0,38458601	0,44016751
47	1,58993562	-0,11956483	-0,31040478	-0,0227227	0,12758330	1,66964173	0,38458601	-0,04400958
48	1,63893807	0,60694671	1,91613505	1,04265389	0,70176898	1,78009038	0,38458601	0,64805068
49	-0,05433554	0,17625214	0,15619279	0,66743003	0,96691505	0,3225788	0,38458601	0,42608148
50	0,53894748	0,56784610	0,72264016	0,84719812	0,70040540	0,55841285	0,38458601	0,40360280
51	0,53894748	0,56784610	0,67810565	1,00677975	0,126671	0,55841285	0,38458601	0,263565
52	0,1862560	0,07585771	0,0683365	0,25164266	0,28710101	0,15078375	0,21250805	0,98523174
53	0,13874533	0,10617350	0,12038293	0,19306438	0,14448418	0,15056891	0,23483636	0,27264656
54	0,33589334	0,41859793	0,1998931	0,40517786	0,4705049	0,19847864	0,23483636	0,5708158
55	0,14004533	0,45878719	0,34909289	0,47089690	0,10176472	0,43121880	0,23483636	0,54274751
56	0,00427956	-0,12012431	-0,39447073	-0,39325693	0,03648121	0,81870846	0,23483636	0,10665745

Table A.9: Gross Product growth rates for the period 1980-1990 (II)

Sect	Italy	Luxembourg	Netherlands	Portugal	Spain	Sweden	U.K.	U.S.A.
1	-0,07536417	0,331678535	0,470458262	0,30324695	0,13713401	0,33253021	0,32526663	0,49769779
2	1,60839779	0,540569444		0,31751275	0,13713401	0,14064399	0,29723079	1,3287192
3	0,33404434	0,640882101	0,441698355	0,20695183	0,13713401	0,49327442	0,03965897	0,34698954
4	0,31044498	0,9141897	-0,172751483	0,28576784	0,07277097	-0,12031218	-0,07005290	0,20411557
5	0,2895040	0,199756046	0,139703111	0,0246976	0,45299397	0,53716768	0,08819650	0,09126791
6	0,01868021	0,419882522	0,063085782	0,08763311	-0,20173984	-0,10605245	-0,1752565	0,25428730
7	0,23462032	9,529147135	-0,023500836	0,75694984	0,10364837	-0,46777750	0,11841506	0,06736927
8	0,16527242		-0,195221828	0,93482073	-0,08571473	-0,47123573	0,02296977	-0,14244957
9	0,17225085	0,698511051	0,16991749	-0,01930423	0,20447814	0,06043271	0,01510942	0,34280496
10	0,09893612	0,44178106	0,431976918	0,53312060	0,42963628	0,36940262	0,05199426	0,20664340
11	0,58684406	0,44178106	0,235585066	0,06849298	1,0449433	0,14174780	0,3388193	0,16440992
12	-0,74317078		0,172545798	0,17701892	0,065990071	1,396375	0,05673805	1,12775137
13	1,01063820	0,942086821	0,604194692	0,28373002	0,99352687	0,33538808	0,41509825	0,44530295
14	0,26405952	0,696380813	1,081439112	-0,20477716	0,4603945	0,20872032	0,27041185	0,84381526
15	0,18208934	0,97364596	0,273382964	0,4641778	0,23842897	0,19179666	0,04819620	0,03100739
16	0,42523106	0,310084975	-0,027759453	0,58302623	0,02606118	-0,05159536	0,16717842	-0,29344929
17	0,20336653	0,455048269	0,22561031	0,01353615	0,07158202	0,24529958	-0,0496774	0,11398741
18	0,01310200	0,172014439	0,309318365	-0,28165749	0,05052693	0,21219440	-0,06269807	-0,17945071
19	12,8899636	7,404084077	10,48825391	2,19026542	29,5377640	8,6605501	15,3279584	12,6187275
20	0,17818031	11,00773691	0,906708281	0,53320084	0,52875908	0,41765235	0,4093370	0,49863515
21	-0,13345497	7,834821942	0,401034795	0,13136182	-0,20531896	0,04241801	0,1054455	-0,0493510
22	7,39244803		5,385404416	4,61274655	3,4215288	5,01683463	4,79159602	11,3504603
23	6,68637763		4,854003052	4,05721860	5,49951006	4,58603058	4,34355639	8,04268172
24	3,09789007		2,110425212	1,71580810	0,97438909	1,97898014	1,97526796	1,09942575
25	0,03590708	0,383822052	0,458564045	0,07153306	-0,00422822	1,60908242	0,39989340	0,32437390
26	0,10179890	0,474014136	0,549014883	0,15329885	0,06207290	1,78105287	0,2846802	-0,04013614
27	0,27221920	1,229061611	0,800603069	0,52854674	0,77484365	0,54615344	0,12420209	-0,00610936
28	-0,07560309	3,856168687	-0,106137326	-0,41645105	0,05145950	-0,7281032	0,61296215	0,24992043
29	1,09263042	3,856168687	0,387608355	0,30892199	2,15413445	0,14627708	0,61296215	0,39934760
30	0,22052033	3,856168687	0,23214042	0,30892199	0,29500810	-0,20693282	0,61296215	-0,05209049
31	-0,02215745	0,545221692	0,20629796	0,17406175	-0,10341150	0,08510532	0,03813095	0,41579172
32	0,05975849	0,531626772	0,215046348	0,44488916	0,44879887	0,55763105	0,46009247	0,29030512
33	0,10494204	0,663487385	0,057965924	0,16016533	0,4457307	0,2000133	0,46009320	0,13494034
34	0,26084690	0,671143087	0,278477665	0,17490848	0,15234847	0,29518867	0,37828170	0,48530964
35	0,26084690	0,765917515	0,431674791	0,17490848	0,20387813	0,29518867	0,37828170	0,53398625
36	0,26084690	0,329244126	0,355073577	0,17490848	0,20387813	0,29518867	0,36371761	0,53922131
37	0,09695769	0,345115026	0,10771038	0,31976380	0,41711525	0,05150071	0,28813595	0,28232464
38	0,27977419	1,118850864	0,44933821	0,34505862	0,30229287	0,26859285	0,31568284	0,15190781
39	0,51899539	1,118850864	-0,028085792	0,34505862	-0,47845167	0,22944728	0,31568284	-0,04578033
40	0,51899539		0,70673722	0,345058624	0,69150093	1,25157120	0,53248427	1,06706861
41	0,51899539	1,118850864	0,141612925	0,34505862	0,45516045	0,56703113	0,31568284	0,65867607
42	0,94847919	1,426933235	0,450904283	1,63863171	0,73414801	0,74774858	0,58883327	0,14083224
43	0,34844927	0,731027097	0,106034114	1,36554418	0,42802258	0,5589131	0,33503831	0,22471448
44	0,34844927	0,65578278	1,35393705	-0,21142085	0,42802258	0,5589131	0,56611435	-0,31264720
45	0,34844927	0,783468151	-0,030013843		0,42802258	0,5589131	0,60442471	0,90258922
46	0,60439754	0,387335926	0,441904652	0,52258936	0,19827484	0,07073937	0,10779884	0,33774483
47	0,60439754	1,542386865	0,757197893	0,52258936	0,51464457	0,75387094	0,77255373	0,5921550
48	0,60439754	1,990774645	0,658789535	0,52258936	0,51464457	0,75387094	1,08975331	4,61928957
49	0,60439754	0,731257941	0,365002684	0,52258936	0,51464457	0,75387094	0,39777412	1,2700203
50	0,60439754	0,731257941	0,503120182	0,52258936	0,51464457	0,75387094	0,52925135	0,47860995
51	0,60439754	0,731257941	0,661767156	0,52258936	0,51464457	0,75387094	0,52925135	1,25913072
52	0,32910339	0,488153003	0,317393784	0,23905354	0,53807702	0,19375530	-0,0311783	0,16040263
53	0,09166545	0,580782758	0,167019318	0,64107833	0,42499216	0,19375530	0,05988165	0,17079041
54	0,21541040	1,306396516	0,137868181	0,44607682	0,42093316	0,19375530	0,19072109	0,27859610
55	0,28496982	0,170099431	0,031928132	0,55313454	0,43422507	0,19375530	0,43661761	0,35960450
56	0,19433650	0,160000555	-0,01555397					0,01436610

Table A.10: Employment growth rates for the period 1980-1990 (I)

	Austria	Belgium	Denmark	Finland	France	Germany	Greece	Ireland
1	-0,17081291	-0,2454505	-0,3065436	-0,29473114	-0,34787725	-0,317240318	-0,146540157	-0,24901406
2	-0,17289694	-0,2454505	-0,15211658	-0,24723578	-0,0727544	-0,011521124	-0,513885023	-0,24901406
3	-0,01248565	-0,1137729	-0,17755171	-0,32894736	-0,10700413	-0,213220481	0,932645405	-0,24901406
4	-0,46526412	-0,67704665	-0,04841869	-0,3060606	-0,30696667	-0,253312544	0,061531944	-0,498060756
5	-0,18482594	-0,16481760	-0,08219358	-0,14167752	-0,0916738	-0,14513963	0,022834417	-0,217305382
6	-0,30086245	-0,26648527	-0,16322991	-0,48840048	-0,37275843	-0,334445552	0,022834417	-0,315992153
7	-0,38304495	-0,35144954	-0,38006913	-0,46408457	-0,36575959	-0,344541689	0,022834417	-0,193855194
8	-0,39080122	-0,40633561	-0,52252079	-0,40750672	-0,33376717	-0,470553413	0,022834417	-0,701778574
9	-0,05770509	-0,14945795	-0,0697938	-0,30998431	-0,25880643	-0,138020423	0,022834417	-0,181275753
10	-0,17576511	-0,15842465	0,05291531	-0,20031136	-0,25315954	-0,043108494	0,022834417	-0,29351517
11	-0,12453383	-0,05765638	-0,09683676	0,0930053	0,05624388	-0,014862339	0,022834417	0,016590621
12	-0,08499723	-0,50106156	0,49127185	-0,12121212	-0,35962197	-0,312860503	0,022834417	0,167101773
13	-0,14554264	-0,02570112	0,0910974	0,04078549	-0,14073526	-0,016615027	0,022834417	0,129408095
14	-0,16641727	-0,0570261	0,0943045	-0,13621262	-0,10776714	0,231619432	0,022834417	0,206567762
15	-0,09386279	-0,36141820	-0,36498992	-0,01932989	-0,27470605	-0,2056525	0,022834417	-0,251200821
16	-0,32513488	-0,40072890	-0,06646959	-0,18108108	-0,31870883	-0,158028754	0,022834417	-0,278308653
17	-0,18391813	-0,23620928	0,03024289	0,14752567	-0,23014786	-0,021332572	0,022834417	-0,235392662
18	-0,09513296	-0,20177366	-0,04302729	-0,03235679	-0,22578342	-0,015127479	0,022834417	0,076679949
19	-0,24460846	0,8859271	0,17771997	0,40579711	0,13613683	0,230963417	0,022834417	0,59297641
20	0,25290271	-0,34258064	0,05882708	-0,40576677	-0,12581908	-0,234625691	0,022834417	0,617625998
21	0,25290271	-0,34258064	0,05882708	-0,03263494	-0,12581908	0,092304797	0,022834417	0,617625998
22	-0,16204966	-0,34258064	-0,13874593	0,81879638	-0,14661671	0,054643093	0,022834417	0,617625998
23	-0,16204966	-0,34258064	-0,13874593	0,41069152	-0,14661671	0,054501526	0,022834417	0,617625998
24	-0,16204966	-0,34258064	-0,13874593	0,4315379	-0,14661671	0,054494246	0,022834417	0,617625998
25	0,0152984	-0,1804366	0,27171867	0,59824023	-0,12738495	-0,040045202	0,022834417	0,291359736
26	0,0152984	-0,1804366	0,27171867	0,13476992	-0,12738495	-0,218222885	0,022834417	0,291359736
27	0,18870218	-0,04685786	-0,35547407	0,10819672	-0,38459686	0,071134603	0,022834417	-0,506626026
28	-0,08654449	-0,42911836	-0,29286718	-0,39149153	-0,49952748	-0,297184653	0,022834417	-0,720922961
29	-0,43770916	-0,42911836	0,49628012	0,60312321	0,09235039	0,357447992	0,022834417	
30	-0,43770916	-0,42911836	0,49628012	-0,22582699	-0,53286448	-0,2222253	0,022834417	0,119989301
31	-0,11000235	-0,29744234	-0,01882627	-0,16097023	-0,20456109	-0,112535965	0,022834417	-0,12309435
32	-0,0211333	-0,14501685	0,0869665	-0,0484048	0,06184521	0,035792512	0,193652316	-0,090144113
33	-0,14070655	-0,28959072	-0,2181656	0,14774245	-0,17444581	-0,071495436	-0,188049667	-0,279844192
34	0,014177	-0,02427841	-0,2497076	0,38237464	-0,08476844	0,027285116	0,285918265	0,054952635
35	0,07923442	0,02933142	0,093905	-0,07176434	-0,01036589	-0,007769859	0,285918265	-0,061443634
36	0,01136284	-0,14291894	-0,12966901	0,04495492	-0,0254896	0,049555694	0,285918265	0,073212581
37	0,10378635	0,07492633	0,09728024	0,1848381	0,16549031	0,232458374	0,285918265	0,099137483
38	0,00719757	-0,21891993	-0,03478063	0,08608679	0,00463741	0,036010183	-0,125802974	-0,09746637
39	-0,06257202	-0,12585623	-0,06034282	-0,25370817	-0,4512952	-0,346873482	-0,125802974	-0,409769047
40	0,2499039	-0,11720773	0,08529558	0,50099037	0,31245173	0,252682632	-0,125802974	-0,010783686
41	0,12909157	-0,00178914	0,20867538	0,16221951	0,17223985	0,036012916	-0,125802974	-0,019522818
42	-0,0064901	-0,1549087	0,03921273	0,16154978	-0,00918016	0,026683295	-0,125802974	-0,0014356
43	0,13900363	0,1381635	0,12075419	0,32236842	0,04030094	0,086978741	0,477919694	0,498447111
44	0,11044348	0,18375089	0,0277606	0,14202898	0,14010279	-0,067644761	0,477919694	0,457499139
45	1,18993853	0,12133190	0,08215478	9,25037588	0,14010279	0,247393228	0,477919694	0,637320659
46	0,02987921	0,36684135	0,3736829	0,18898488	0,42987761	0,257928185	0,477919694	0,68030842
47	0,11890107	-0,25176716	0,47417951	0,19354838	0,36789193	0,241037789	0,477919694	-0,112538808
48	1,17079137	0,36859965	0,81561524	1,13448275	0,34347605	0,579418053	0,477919694	0,679133031
49	0,3743189	0,0004188	-0,02613978	0,50684931	0,19859771	0,237474587	0,477919694	0,274043149
50	0,47063591	0,33523559	0,15922916	0,90401122	0,18099548	0,4415951	0,477919694	0,555821675
51	0,47063591	0,33523559	0,31477	0,88762516	0,18099548	0,4415951	0,477919694	0,555821675
52	0,02704691	0,10686416	0,00308598	0,12685241	0,09852754	0,027704223	0,437236507	0,054433158
53	0,1902192	0,05975791	0,04791842	0,16118811	0,05948932	0,089511054	0,437236507	0,054433158
54	0,357408	0,08539669	0,1615578	0,30612837	0,06427896	0,344636842	0,437236507	0,054433158
55	0,23595234	0,08539669	0,15540434	0,32282003	0,38189311	0,250235541	0,437236507	0,054433158
56	-0,35339373	0,08539669	-0,3819706	-0,38248847	0,38189311	0,733336553	0,437236507	0,054433158

Table A.11: Employment growth rates for the period 1980-1990 (II)

Sect	Italy	Luxembourg	Netherlands	Portugal	Spain	Sweden	U.K.	U.S.A.
1	-0,42721078	-0,16050176	0,051039225	-0,29285217	-0,380763	-0,27214872	0,0205004	-0,1493043
2	-0,42721078	-0,16050176	0,45618215	-0,15026595	-0,31960492	-0,18106631	0,0205004	-0,14149821
3	-0,13065822	-0,08509321	-0,018717316	-0,22202277	-0,380763	-0,17895317	-0,11816157	0,40486178
4	-0,08121231	-0,27993138	0,259259259	-0,13058916	-0,18600642	-0,28238735	-0,53855741	-0,25036994
5	-0,00296008	7,07442E-05	-0,167670393	-0,11108539	-0,12932703	-0,04291521	-0,22735228	-0,02409551
6	-0,22061878	-0,52596182	-0,311262854	-0,22234861	-0,42087717	-0,39489256	-0,37186151	-0,10052411
7	-0,09240805	2,44391596	-0,524265083	0,15749962	-0,23747408	-0,39489256	-0,24515622	-0,20667554
8	-0,18787877		-0,43057035	0,327169373	-0,43406786	-0,5846456	-0,28615869	-0,40945176
9	-0,22195326	0,0460853	-0,333052663	-0,20773594	-0,2017433	-0,0765917	-0,00326831	0,02430778
10	-0,07061074	-0,06386659	-0,101010101	-0,04725464	-0,24490214	-0,00724369	-0,24432529	0,0256434
11	-0,03009733	-0,06386659	-0,071378158	0,1370239	0,06903402	0,09767334	0,00227940	0,29391711
12	-0,108512		-0,09716326	-0,130589166	-0,26048016	0,17185815	0,03605866	-0,18806061
13	-0,18623757	0,02879574	-0,003535178	-0,09600274	-0,12105184	0,03738252	-0,22160932	-0,02695871
14	0,11472642	-0,14654605	0,192612783	-0,03135499	-0,04230716	0,06010075	-0,07831574	0,19848562
15	-0,05891668	0,2002163	-0,254228681	-0,13058916	-0,29893582	-0,1913183	-0,24286279	-0,15424878
16	-0,26153854	-0,18324533	-0,201612903	-0,20211221	-0,4124881	-0,30104182	-0,47239793	-0,32608269
17	-0,13078716	0,09729793	-0,10902686	-0,11249173	-0,27174553	0,03223303	-0,28787675	-0,10800519
18	-0,12262588	-0,0963844	-0,04956558	-0,11790176	-0,24416741	0,04574244	-0,23110902	-0,13810029
19	0,15661644	-0,68050054	-0,086877333	-0,02659213	-0,00620467	-0,09501265	0,07246207	-0,13965139
20	-0,13575602	2,74741725	-0,086877333	0,19130958	-0,29525139	-0,09501265	0,00847652	-0,11460223
21	-0,13575602	2,74741725	-0,086877333	0,19130958	-0,36158871	-0,09501265	-0,33034654	-0,11512703
22	-0,26423102		-0,08687733	-0,174024396	-0,29533644	-0,09501265	-0,05409348	0,25609832
23	-0,26423102		-0,08687733	-0,174024396	-0,39938355	-0,09501265	-0,24052201	0,11478908
24	-0,26423102		-0,08687733	-0,174024396	-0,43478876	-0,09501265	-0,24365637	-0,26759025
25	0,01275229	-0,43074665	-0,086877333	-0,04082884	-0,23332588	-0,09501265	-0,16143449	0,04360468
26	0,01275229	-0,43074665	-0,086877333	-0,04082884	-0,25609755	-0,09501265	-0,2295389	-0,31828996
27	-0,37418901	0,36747031	0,234485945	0,23504667	-0,10088898	0,32297947	-0,39848904	-0,02955434
28	-0,05347367	1,97188325	-0,562574029	-0,53792073	-0,37185127	-0,32232796	-0,55547092	-0,12674641
29	0,68966387	1,97188325	-0,104263326	-0,34344773	0,13937275	-0,32232796	-0,23539309	0,23597708
30	0,01946342	1,97188325	0,250011372	-0,34344773	-0,33310445	-0,32232796	-0,22856948	-0,36033343
31	0,02123073	0,15131012	-0,198889145	0,02912668	-0,34352813	-0,05298719	-0,11494538	0,04201498
32	0,13298149	0,03408069	-0,054216867	0,12802731	-0,00774434	0,06626455	-0,16212277	0,16245252
33	-0,13213727	0,28809099	-0,255555566	-0,12030555	0,01590993	0,06743063	0,20741275	0,20097398
34	0,15343297	0,10869812	-0,118627005	0,02876905	0,15660363	0,02841169	0,10695897	0,43692256
35	0,15343297	0,09350629	0,037796826	0,02876905	0,24707023	0,02841169	0,10695897	0,16560858
36	0,15343297	0,03660779	0,002099672	0,02876905	0,00026669	0,02841169	0,0411233	0,13860493
37	0,28809685	-0,05094404	0,148287693	0,26704648	0,30435318	0,2986499	0,28803019	0,40036977
38	0,05579472	0,16159451	0,124057501	-0,03952621	-0,03504616	0,13822922	-0,29181656	-0,02419879
39	0,0313987	0,16159451	-0,258094442	-0,03952621	-0,4946419	0,13822922	-0,52616816	-0,06729672
40	-0,19827599		0,12080536	-0,039526212	-0,17317548	0,13822922	0,2826732	0,86881554
41	-0,12444509	0,16159451	0,138073041	-0,03952621	-0,06546237	0,13822922	-0,04936018	0,84072351
42	0,04387213	0,16159451	0,120410946	-0,05710067	0,21651925	0,15300088	0,04400167	0,02571495
43	0,31588797	0,45494978	0,029268293	0,11660667	-0,07031884	0,23026179	0,43616804	0,24887156
44	0,31588797	0,12020496	0,072115385	-0,07250456	0,08487972	0,35895625	0,23314125	0,14811859
45	0,31588797	1,68860979	0,283624565		-0,08668494	0,2623832	0,6435526	0,63792351
46	1,2681165	0,33355863	-0,147157986	0,56715734	0,16712763	0,51856745	0,67236316	0,3098389
47	1,2681165	0,12040142	0,415311005	0,56715734	1,26438776	0,51856745	0,28735166	0,88875982
48	1,2681165	1,24080285	0,530807961	0,56715734	0,55074667	0,51856745	1,01799528	2,04015425
49	1,2681165	0,41359081	-0,057971014	0,56715734	0,38346694	0,51856745	-0,16011032	0,59933065
50	1,2681165	0,41359081	0,49936792	0,56715734	0,59276423	0,51856745	0,47943409	0,68474416
51	1,2681165	0,41359081	0,727325329	0,56715734	0,59276423	0,51856745	0,47943409	1,19987649
52	0,0994693	0,0036034	0,006896552	0,2407585	0,54684753	0,19636574	-0,15597752	0,0757653
53	0,19018443	-0,00196363	0,03280543	0,50173625	0,17267352	0,19636574	0,10765685	0,19928013
54	0,15449804	0,23650018	0,092584037	0,36862931	0,32043042	0,19636574	0,29133397	0,50071414
55	0,43758779	0,21442403	0,033394685	0,00545417	0,38721469	0,19681734	0,24225734	0,28795495
56	1,44796066	-0,06332537	-0,188332123			0,19636574		-0,15972501

Table A.12: Gross Product growth rates for the period 1990-2001 (I)

Sect	Austria	Belgium	Denmark	Finland	France	Germany	Greece	Ireland
1	0,51399828	0,36312939	0,35691922	-0,0190814	0,27116505	0,15761725	0,04650642	-0,018290355
2	0,26809982	0,62822990	0,28545211	0,09077257	-0,2346285	0,1209193	-0,0904493	0,071805789
3	0,4739497	0,21993861	-0,01045655	0,01743841	-0,0827450	0,02736607	0,4028942	-0,101911897
4	-0,22943411	-0,3448443	1,14020893	0,14953760	0,43644232	-0,4296998	0,03748097	1,846609649
5	0,17053417	0,03596059	-0,0288778	0,15930617	0,00153551	0,12966195	0,28442632	0,33313838
6	-0,20360604	0,29345834	-0,0521134	0,0223486	-0,0785364	-0,4046939	-0,2544423	-0,462959212
7	-0,33845415	0,17449167	-0,2197349	-0,5578695	-0,2413828	-0,4412762	-0,2584889	-0,365024146
8	-0,27675676	-0,5353808	-0,2287548	-0,3763435	-0,4049119	-0,4125695	-0,1502649	-0,286920876
9	0,24639025	0,17662013	0,22990811	0,33073834	0,05562513	0,33007792	-0,0228581	0,589330606
10	0,72253368	-0,0526595	0,34184634	0,48092941	0,27601728	0,26386218	-0,0660136	0,27732104
11	0,20370528	0,27138785	-0,1116162	0,02824951	-0,0356334	-0,0324485	0,14046963	3,413079113
12	16,9652132	-0,4520029	-0,4467225	0,54827006	0,12050369	-0,4362408	0,79041939	1,948397884
13	0,36759014	0,56920683	1,3050476	0,37155773	0,44142550	0,14962722	-0,0376914	4,894534519
14	0,83384750	0,53799636	0,2362211	0,34345148	0,33723081	0,20070517	-0,1888579	0,068999595
15	0,0139980	0,08713946	0,0629955	-0,0356009	0,04363505	0,12106233	0,27673668	0,099781808
16	0,24660281	-0,1839744	0,2312108	0,67908736	0,0084041	0,01258101	-0,3293231	-0,118579522
17	0,43174120	0,44971015	0,1434026	0,46433385	-0,0016093	0,10140825	0,30039635	0,200904351
18	0,2736950	-0,0572788	0,1040196	0,19823578	0,21830326	-0,1408071	0,50699142	-0,080954225
19	342,459375	19,281877	31,624219	3,30507598	26,475185	26,780417	60,568815	110,5095199
20	0,90764090	-0,2825978	-0,1765816	0,26869748	0,2131340	-0,0036641	0,51456912	1,133730234
21	0,60510128	0,00546007	0,30579805	0,3594083	0,11230644	-0,0673815	0,40576761	0,920859011
22	85,3759513	94,542777	49,340003	180,64212	87,726130	150,2340	52,217634	1042,615146
23	-0,06638473	-0,1408037	0,978499	8,43525243	0,0431468	-0,1025755	0,13434073	0,77787218
24	-0,586968	-0,4473950	-0,3032309	-0,8521058	-0,6269449	-0,7670682	-0,6471530	-0,202364393
25	-0,28296089	-0,222549	-0,3646015	0,37031217	-0,4751863	-0,4085071	-0,3870376	0,262191179
26	-0,17857560	0,1555405	3,5007653	1,3779308	0,00400041	0,09696707	2,15455826	1,259786547
27	0,96548799	0,0598179	0,31948728	-0,004124	0,56525751	-0,03400985	0,80763802	0,108949466
28	-0,232127	0,13314648	-0,2623409	0,29496560	0,72065738	-0,4192842	0,52270893	-0,344068992
29	0,46804105	1,40775819	0,24378835	0,86608082	-0,1401059	0,60650269	-0,0434554	
30	0,03913204	-0,0484047	0,22983212	-0,7377333	0,3932553	-0,024138	-0,0833913	0,300831926
31	0,15509679	-0,0169374	-0,0268727	0,07289188	0,01915291	-0,2044607	-0,0802401	0,367727975
32	0,31736475	0,41476217	0,13949309	0,23449706	0,30634886	0,15760193	0,5454049	1,079516469
33	0,41591388	0,12369350	-0,063160	-0,2213673	-0,1571990	0,02451841	0,11401400	1,628046375
34	0,09662175	0,16753526	0,15551898	0,07687268	-0,0118095	0,06660418	0,29371492	0,264388695
35	0,28109302	0,01720289	0,50642687	-0,0654355	0,29505326	0,34430437	0,28644732	0,121698681
36	0,38583474	-0,1517678	0,33233176	0,04677225	0,20310533	0,33234466	0,2300343	0,539263776
37	0,11564971	0,10080298	0,26456431	0,08327448	-0,0422572	-0,0994956	0,24205938	0,742215017
38	0,38215268	0,15923687	0,07245553	0,16531453	0,14964520	0,14550441	0,36042064	1,6620775
39	0,09429596	-0,3930985	0,48054432	0,67358466	0,17861246	1,33675012	0,7093387	0,627326506
40	1,79378344	0,42521831	-0,1823656	0,65519073	0,61397106	1,70395178	0,43430778	2,430660285
41	0,26301054	0,33372174	0,23056217	0,40005457	0,42119112	0,92906836	0,56525966	1,925906932
42	0,52930630	0,46455047	0,72452283	1,30885739	0,71820205	1,21782693	0,92193888	0,919436689
43	0,54214654	0,48114161	-0,0133657	-0,0873537	-0,2151632	0,81092086	0,60258552	1,717893369
44	0,18267900	0,18947907	-0,0005255	-0,1882912	-0,0356678	-0,1026344	0,70076115	1,373783909
45	0,44626307	0,04105809	-0,4655548		0,23998681	0,2790029	1,40333782	3,41084605
46	0,18473855	0,77654652	0,10254579	0,37922243	0,17099886	0,38253771	0,33959413	0,981096033
47	1,26237624	2,27645761	2,19514385	0,07558186	0,17533076	0,93264234	0,5759498	5,264521894
48	1,66468202	1,34720111	2,04545600	0,86609233	0,76263181	1,7247880	3,37097274	4,44977709
49	1,7670131	-0,26249727	-0,1154435	0,27049217	-0,0033612	0,57028017	1,28120497	-0,012942937
50	0,59874072	0,09212185	0,16765033	0,30638212	0,26378619	0,62103703	0,52600678	0,542675356
51	0,94758440	0,91958714	0,84428697	0,2518696	0,40138234	0,62103703	0,52600678	0,760528845
52	0,22882423	0,15838385	0,17837312	0,0311452	0,20311369	0,06035168	-0,0619281	0,321602559
53	0,07531099	0,1022389	0,13836234	0,11511319	0,21431409	0,11090591	0,23538578	1,415212278
54	0,04780255	0,1791426	0,17191363	-0,0050010	0,19642325	0,44196146	0,2119465	0,668040848
55	0,11919691	0,3060503	0,34493312	0,14165683	0,19378496	0,21575743	0,38651503	0,281234871
56	0,17745964	0,07307804	0,10425374	1,47222439	0,42444605	0,46667305	0,82242306	0,054716188

Table A.13: Gross Product growth rates for the period 1990-2001 (II)

Sect	Italy	Luxembourg	Netherlands	Portugal	Spain	Sweden	U.K.	U.S.A.
1	0,20900269	0,584612935	0,329698193	0,20583377	-0,100436047	-0,295114961	0,00196720	0,87851405
2	-0,0889139	0,341605415	-7,806332267	-0,0620305	-0,285304493	-0,025143268	0,01525266	-0,0871201
3	0,08468527	0,397460387	0,067269335	-0,1929318	-0,158827404	-0,243147064	-0,01200489	-0,1938456
4	0,00894275	0,551822391	0,088316548	0,44313050	-0,070868394	0,032367629	0,43399850	0,03777049
5	0,12976393	-0,20929569	0,356301613	-0,0285707	0,062990097	0,222076369	0,04451543	-0,0574902
6	0,06563947	3,928186147	0,096878651	-0,2373532	0,104452406	-0,096598202	-0,2735091	-0,0019592
7	0,12490010	-0,410749075	-0,349213932	0,0968388	0,225531596	-0,450712244	-0,3416488	-0,1710270
8	-0,0585983		-0,1832635	-0,0147794	0,0106977	-0,171330881	-0,2780636	-0,3509877
9	0,27460024	5,269294968	0,269932078	0,3728257	0,276931194	-0,043357206	-0,1917404	-0,105774
10	0,43480273	-0,39806715	0,17109165	0,7308661	0,661880958	-0,062260709	-0,0382379	0,04680905
11	0,07679376	0,054199803	0,320150643	0,2440511	0,160646826	0,455892688	0,07451653	-0,1416783
12	-0,3922384		-0,246327372	0,36059247	-0,176673	0,904968206	0,03236214	0,26903929
13	0,18465825	0,458389611	0,225937666	-0,1514569	0,352293252	0,820306774	0,3209613	0,27164215
14	0,27168590	0,630069739	0,356137675	-0,104087	0,717298591	0,453320804	0,16275667	0,73893692
15	0,13985284	0,007905037	0,125198051	0,72454976	0,336303407	-0,253022522	-0,146303	0,26903667
16	0,05487705	0,428631474	0,009520219	-0,2374448	0,329166698	0,164754472	-0,1509133	0,29499065
17	0,20696074	0,504318197	0,228330964	0,44104493	0,556320432	0,202733402	-0,134841	0,29250474
18	0,14996767	-0,201419893	0,400783417	-0,0751956	0,473798489	0,159728005	-0,1766002	-0,0045859
19	26,2253186	107,1841647	57,85154446	51,144853	37,97683116	20,498029	27,729830	38,253752
20	-0,1045386	-0,634422555	0,820060806	0,5210002	0,081513126	1,17154544	-0,0665125	0,2003730
21	0,16169129	-0,732621432	-0,132853721	0,59157827	0,275800924	0,22192296	0,054681559	-0,1460915
22	70,2316149		56,56282376	77,58469899	82,6483852	43,52265613	62,311932	100,9959
23	-0,4503395		-0,142700034	3,679170438	-0,6309442	0,409626867	1,50817091	0,34048725
24	-0,6383503		-0,535503784	-0,379778537	-0,4077619	-0,820904214	-0,0547287	-0,540181
25	-0,5504231	0,282126812	-0,401159193	0,84050834	-0,243193282	-0,05519944	-0,3722521	-0,4492839
26	0,32020627	2,215998294	0,671578022	3,87305516	1,060466344	1,872152974	0,51393430	0,03391807
27	-0,1020625	-0,612274955	0,716718394	3,36321119	0,426478977	1,198430909	0,0926550	0,59282985
28	-0,2382915	1,408821298	-0,077940208	-0,2915129	0,118578348	0,159456528	-0,1651782	-0,1977207
29	-0,3370917	1,408821298	0,096593297	2,43497087	1,034711139	-0,226663689	0,02860433	-0,3538583
30	0,34363321	1,408821298	0,899060079	4,77376906	0,818571924	-0,233991189	-0,382508	0,62789436
31	0,29239748	1,967512164	0,234048757	0,60606910	0,498062925	0,489877952	-0,0411214	0,27781438
32	0,15079438	0,64619173	-0,018279709	0,45760196	0,338814894	0,037463827	-0,0009161	0,1347645
33	-0,0070097	0,404095862	0,056564838	0,35891929	0,266331062	-0,164219555	-0,0009185	0,2704710
34	0,25141570	0,61359157	0,28435413	0,43019249	0,257812411	0,373339552	0,51608341	-0,0223016
35	0,29469450	0,908220856	0,565295618	0,43021358	0,259982431	0,363522432	0,82179577	0,87736291
36	0,11200984	0,333609734	0,360429125	0,28731660	0,261276756	0,311047298	0,2030466	0,62427984
37	0,16343838	0,161900726	0,340165167	0,07162700	0,256036024	0,163958325	-0,0455837	0,13669576
38	0,09506472	1,488949749	0,250027822	0,28364828	0,555279221	0,313770511	0,32171053	0,43232726
39	-0,2343934	1,488949749	0,302713196	-0,2610902	0,307426822	-0,226350003	-0,2139242	0,27091882
40	0,09245593		1,340338079	0,119550637	0,8223789	0,407142747	3,60938965	0,84759583
41	0,44494542	1,488949749	0,428087034	0,35599514	0,135936177	0,474760875	0,73842052	0,61900358
42	0,96009160	3,254170884	1,230381499	1,06678101	0,854432982	0,762750354	1,16675821	0,75849939
43	0,36085277	0,825682709	0,412042219	0,34937125	-0,172161321	0,30761346	0,30009331	0,33251997
44	-0,0534003	0,376062156	0,204044231	-0,742513	-0,401833904	1,161716245	0,16084663	0,22997389
45	0,05351633	1,882420194	0,672568471		0,0204522	2,366148228	0,43082281	1,47743804
46	-0,0073262	0,40938522	0,285238143	0,1951319	0,214758577	0,118463151	0,17217097	0,31673566
47	0,56695774	0,524950622	1,074845264	1,13858334	0,492861099	-0,011775015	0,44242813	1,19752012
48	0,90780077	3,147615015	2,088091183	2,34443194	0,822406774	1,250961189	1,8832761	1,44686751
49	0,22270481	0,764825882	0,06711632	14,282480	0,526808436	0,227327404	-0,3225817	0,38750075
50	0,46387938	0,999605458	0,617640723	-0,1265660	0,543868361	0,346932316	0,84125702	0,22306996
51	0,38102300	0,772924791	1,055245524	1,13261784	0,569137837	0,346932316	0,47500678	0,73874492
52	0,12640418	0,248134922	0,048536746	0,09183322	0,279715543	-0,135497333	-0,0414428	0,04137351
53	-0,0667413	0,426283784	0,167141465	0,35260496	0,329280132	0,155512108	0,1971743	0,06731135
54	0,07867177	1,564317303	0,185356643	0,19701269	0,344874637	0,142872173	0,4081633	0,16277086
55	0,26599035	0,072533783	0,244509651	0,55327435	0,201079312	0,20243427	0,45588661	0,18667432
56	0,20282552	0,221714633	0,271636851					0,05268183

Table A.14: Employment growth rates for the period 1990-2001 (I)

Sect	Austria	Belgium	Denmark	Finland	France	Germany	Greece	Ireland
1	-0,26840518	-0,22424863	-0,34461806	-0,334105192	-0,360062867	-0,382669221	-0,19857033	-0,26681461
2	-0,33419897	-0,39037739	-0,0106981	-0,416940924	0,217650685	-0,10306247	-0,13391864	-0,196548
3	-0,27925541	-0,35225959	-0,3137985	-0,235294118	-0,09487217	-0,321356044	0,29184756	-0,07899061
4	-0,31272427	-0,65325078	0,10822666	-0,161572052	-0,421729887	-0,61530017	-0,39493173	-0,15250917
5	-0,22479562	-0,12092549	-0,1706227	-0,284556962	-0,036489436	-0,033032892	-0,02448871	-0,04582904
6	-0,43556013	-0,2335613	-0,36550052	-0,38902148	-0,337974797	-0,487392176	-0,21032287	-0,46906025
7	-0,58991726	-0,71139306	-0,59815741	-0,620236531	-0,497694531	-0,646174412	-0,27577291	-0,65319143
8	-0,40868237	-0,49851813	-0,55269083	-0,515837104	-0,427841108	-0,582359023	-0,30821449	-0,53638523
9	-0,11179629	-0,01326969	0,17943076	-0,222727273	-0,209492931	-0,11108743	-0,19632156	0,28814799
10	-0,19998796	-0,25872613	-0,13457451	-0,1862427	-0,154387707	-0,077060543	-0,00939577	0,03425292
11	-0,1665584	-0,18146155	-0,10399578	-0,268635724	-0,116214242	-0,263876385	0,0496815	0,45618581
12	-0,42124949	-0,23302822	-0,34995124	-0,025862069	-0,355142235	-0,463147967	-0,16249976	0,13463801
13	-0,20343888	-0,14040979	0,08418162	-0,111756168	-0,185839309	-0,276257983	-0,12395501	0,47692365
14	-0,04516158	-0,06129173	0,00595087	0,161538462	-0,012307497	-0,008442761	-0,00310817	0,20675691
15	-0,19970337	-0,15169351	0,00097659	-0,282522996	-0,194676227	-0,170746216	-0,11199959	-0,05524677
16	-0,3542671	-0,35382872	-0,10471005	-0,080858086	-0,272994578	-0,426870391	-0,01616934	-0,00741499
17	-0,04265001	-0,0113891	0,02726617	0,086248983	-0,092645318	-0,049284087	-0,04856019	0,19893106
18	-0,08133391	-0,23149058	-0,06989049	-0,075915047	-0,131149118	-0,264299983	-0,02118662	0,05543026
19	-0,04058912	-0,45866339	-0,39825678	-0,494845361	0,173068027	-0,514901684	0,86334101	1,5194218
20	0,28572916	-0,47341334	-0,12365366	-0,354512334	-0,224200535	-0,027405162	-0,10275167	1,3632144
21	-0,20400612	-0,23218244	-0,06202545	-0,053245735	-0,043664908	-0,2354869	-0,00428679	0,23248793
22	0,42804456	-0,04380643	-0,27700757	0,920197894	0,266459574	0,584739897	-0,03750282	3,01823278
23	-0,29617639	-0,34517426	0,48267618	2,982601645	-0,326963101	-0,493844663	0,03656322	1,32106299
24	-0,39744597	-0,20775832	0,06531562	-0,75482427	-0,397403832	-0,565514994	-0,44221959	0,62143525
25	-0,00929629	0,2453901	-0,08013791	1,003618856	-0,059568077	-0,135458954	0,38038679	1,17382485
26	-0,6646075	0,03572208	0,64171808	0,371027577	-0,427709927	-0,28506616	4,06203196	0,34190289
27	0,23977492	-0,26003181	0,18102167	-0,25739645	-0,179334954	-0,000340542	-0,17775802	-0,03512924
28	-0,81963881	-0,12387147	-0,15460924	-0,165119842	0,070005991	-0,396020094	-0,27312353	-0,36101593
29	-0,32868899	0,34105071	3,12734255	-0,040708923	-0,285749729	0,048632881	-0,17305003	
30	-0,3439465	-0,47160957	-0,12590855	-0,526067065	-0,011002215	-0,367229251	-0,06711234	0,02606298
31	-0,10700039	-0,24505304	-0,0718822	-0,159001314	-0,162721133	-0,217243834	-0,1346628	0,08697625
32	-0,07222541	-0,20238181	-0,0190386	-0,342196532	-0,055500082	-0,268480464	0,15412581	-0,41270518
33	0,00980783	0,04103633	0,09362593	-0,238943203	-0,164492257	0,102469572	0,13131769	0,83327852
34	-0,07330641	0,02599427	0,02633799	-0,148647566	0,087671056	0,049760309	0,27440654	0,24464801
35	0,01522403	-0,09387717	0,11489666	-0,057369662	0,026486898	-0,046369803	0,33365877	0,1226567
36	0,01247179	-0,17556021	0,03379365	-0,186840976	-0,00931535	0,035864396	0,23388695	0,48751084
37	0,04037668	-0,0075452	0,23587329	-0,048885694	0,033716161	0,286076717	0,33498725	0,80966062
38	-0,00791163	-0,06124024	0,02923451	-0,101497898	0,069613212	-0,171048135	0,01480139	0,14046043
39	0,09657417	-0,73606297	0,15628838	0,05733261	-0,295033834	-0,344775906	0,00489147	-0,03078752
40	0,22214138	0,41986674	0,16760912	0,170117907	-0,055530206	-0,079601944	-0,06726719	0,19709916
41	0,0605112	0,23021035	0,13724095	-0,02918703	0,268196667	0,083531957	0,00520767	0,31360869
42	-0,1540989	-0,06171547	-0,03334181	-0,080553807	-0,021021832	-0,34587207	0,14152188	0,10672043
43	-0,09224585	0,03703088	-0,09962636	-0,532338308	-0,122118186	0,004728728	0,56449927	0,5827284
44	-0,12004423	-0,16508952	-0,09979095	-0,180203046	-0,030201914	-0,026190059	0,3858478	0,2335765
45	0,99865804	-0,27686789	-0,08088606	0,795918367	0,134652613	0,197516604	0,66023851	1,25396299
46	0,13182904	0,35706199	-0,02594524	-0,078110808	-0,087457383	0,70473615	0,27675038	0,50066069
47	0,2805738	0,65591181	0,03475543	-0,060810811	0,513227523	0,376491227	0,03537071	1,2722342
48	1,57425565	0,65307176	0,17303045	1,069466882	0,682386006	0,903883217	1,90273788	3,75897396
49	0,30635916	-0,46658894	-0,1348552	0,342424242	0,07467157	0,221002597	0,87733996	-0,2783071
50	0,35053816	0,14166457	0,1429696	0,118117131	0,167524007	0,765916991	0,61554252	0,80756804
51	0,44450091	0,37933012	0,5889083	0,475837221	0,562537209	0,765916991	0,61554252	1,05741989
52	0,01950544	0,00155997	-0,0114558	-0,008942662	0,127609069	-0,172085948	0,131339	0,21657184
53	0,05796635	-0,07613043	0,09533261	0,163028649	0,105487428	0,022633423	0,31354494	0,24014601
54	0,09855904	0,08979517	0,21027675	0,052590616	0,095571802	0,302820721	0,31004676	0,37022683
55	0,09523577	0,00709251	0,24938144	0,131837307	0,458424116	0,185042721	0,19128291	0,5042029
56	0,11414485	0,18125589	0,37386402	1,507462687	0,666779964	0,358633692	1,40832219	-0,10556909

Table A.15: Employment growth rates for the period 1990-2001 (II)

Sect	Italy	Luxembourg	Netherlands	Portugal	Spain	Sweden	U.K.	U.S.A.
1	-0,3608542	-0,33602178	-0,14648882	-0,28110985	-0,30794382	-0,12537065	-0,27429198	0,046046138
2	-0,37330445	-0,4782141	-0,71185092	-0,54904412	-0,33041423	-0,47940713	-0,26280679	0,152478169
3	-0,19619342	-0,47942597	-0,02052264	-0,38928698	-0,09133892	-0,00653659	-0,22225595	-0,248659052
4	-0,26686392	-0,0460332	-0,12497709	-0,11836736	-0,42093696	-0,16786304	-0,5801314	-0,245327019
5	-0,03926568	0,08118912	-0,11560375	-0,15565304	-0,00895129	-0,12648896	-0,08153166	0,036266787
6	-0,09393891	0,77905322	-0,3606382	-0,38422225	-0,08720019	-0,51030834	-0,38501124	-0,203178944
7	-0,28614281	-0,77932788	-0,4740497	-0,15218754	-0,08536977	-0,34278386	-0,49292558	-0,415360029
8	-0,22615482		-0,51087675	-0,23605356	-0,17296157	-0,51653925	-0,61095401	-0,4474195
9	-0,08657737	1,34070655	-0,13306786	-0,06591682	0,09949688	-0,10802261	-0,16062253	0,121929429
10	0,08245558	-0,26576557	-0,16130783	-0,30592128	0,16830309	-0,1232446	-0,1980052	-0,047629727
11	-0,02906417	0,2844301	-0,09171356	-0,07925099	0,17273948	-0,19774776	-0,00363446	-0,013159163
12	-0,13415861		-0,21183932	-0,30537097	-0,04342711	-0,03935986	-0,13117343	-0,18821801
13	-0,08051335	0,84410974	-0,22909955	-0,36766801	-0,03404144	0,19460948	-0,25051257	-0,03376984
14	0,11166106	-0,06992501	-0,00201711	-0,06193443	0,29579442	0,06494559	0,01243098	0,146455172
15	0,00242213	-0,13416515	-0,0901894	-0,06451565	0,1127945	-0,2756836	-0,34074156	0,039808873
16	-0,0913211	-0,49370351	-0,23314763	-0,2297792	-0,17022753	-0,18394512	-0,38621102	-0,049222342
17	-0,07717774	0,08508748	0,01820164	-0,03839127	0,34864012	-0,04797643	-0,21250714	0,090818245
18	-0,00916273	-0,16527889	0,09045865	-0,13654656	0,16970108	-0,01728633	-0,26951545	0,035871211
19	-0,21912857	2,19903306	-0,04577984	-0,66043841	0,06924029	-0,57871225	-0,15039664	-0,319001576
20	-0,3445925	-0,63179513	0,07066681	0,39165681	-0,10595392	0,03084226	-0,17981224	-0,043884462
21	0,0680753	-0,63179513	-0,23673219	0,11688426	0,10349391	-0,07844672	0,01025338	-0,126793833
22	0,06789575		-0,20427694	-0,3541228	0,4318369	0,65731858	-0,52042883	0,2115756
23	-0,1014021		-0,20427694	1,86394396	-0,39949628	0,95176395	0,00127833	0,02890608
24	-0,24562367		-0,20427694	-0,3890188	0,24302185	-0,37871634	-0,2744199	-0,1424711
25	-0,01293651	2,58721702	-0,21777018	0,03684305	0,13625349	0,34151863	-0,1148306	-0,135383154
26	-0,1525051	2,58721702	-0,07410183	-0,11157308	0,30580822	0,62516221	-0,20254131	-0,315257103
27	-0,20985322	-0,57490694	-0,04696863	-0,03417707	0,19374534	0,02943085	-0,16202949	0,307000753
28	-0,25796039	1,69151611	-0,14790521	-0,60209653	-0,01553426	0,09787255	-0,38748683	-0,127138617
29	-0,19053827	1,69151611	-0,29057706	1,17833321	0,70703917	-0,14142546	-0,23562231	-0,370243115
30	0,00425853	1,69151611	-0,5352824	0,77751721	-0,08904254	-0,33557304	-0,30437505	0,682640551
31	-0,0709177	0,36521598	0,02620721	0,02460983	0,23710214	-0,17345628	-0,01958752	0,046908712
32	-0,1646501	0,02197304	-0,23879152	-0,520306	-0,07629627	-0,01394783	-0,53169613	-0,068298653
33	-0,01603451	0,27688343	0,10414243	0,12870517	0,19503	-0,23250064	-0,2378157	0,248263082
34	-0,01507628	0,1801429	0,0961671	0,04281699	0,14001535	-0,01238816	-0,11021661	0,203974604
35	0,19214602	0,24240569	0,24731404	0,05803929	0,16355075	0,09093253	0,0084927	0,099289073
36	-0,05445535	0,13965249	0,18592337	0,17058513	0,2018149	-0,14124462	0,01257293	0,097728992
37	0,25780693	0,36994095	0,38429745	0,01172749	0,25977433	0,06273664	0,06489928	0,204541006
38	-0,14030417	0,43943442	0,19552255	-0,11316741	0,04345015	-0,05480024	-0,74039984	0,304191712
39	0,08443655	0,43943442	-0,28735349	-0,28659048	-0,24472793	0,06759938	-0,54262924	0,096757341
40	-0,19710339		0,19997518	-0,04111389	0,1565591	0,05912035	0,68755702	0,33152593
41	0,6555215	0,43943442	0,0959658	0,00395365	0,69024834	0,26302152	0,1058063	0,414409107
42	-0,18701364	0,32445192	0,36283675	-0,20713098	0,16364114	-0,14634619	-0,02111082	0,184192541
43	0,03583976	0,40032349	0,20826391	0,01904075	-0,16031246	0,00491551	-0,06144057	0,065886762
44	-0,05635992	0,77149768	0,17402836	-0,10226925	0,28884029	0,00418099	0,04640792	0,120984627
45	0,10787407	1,92965605	0,55213133		0,51604235	0,51671661	0,27104179	0,37576554
46	0,00861875	0,79332581	0,46444812	1,07504604	0,31752598	-0,20872374	0,59844898	0,148522057
47	1,20569718	0,7711869	0,6610299	0,97995715	0,24736425	0,11812506	0,18034428	0,190835276
48	0,54868266	4,38168351	1,9694267	2,20123169	1,84292292	0,92946517	1,27211406	1,735202532
49	-0,07025232	1,33572902	0,46549393	2,47074855	0,00563146	0,32808648	0,05218854	0,241605916
50	0,43830955	1,91730183	0,6606558	1,30469425	0,36933926	0,31962955	0,18320259	0,308632251
51	0,61888184	1,84941397	0,79948202	1,34730345	0,68404858	0,31962955	0,40645042	0,776625806
52	-0,11255903	0,12416598	-0,13161075	0,04696366	0,14012398	0,00510839	-0,02203634	-0,011583989
53	-0,0920246	0,37050891	0,08401636	0,25821688	0,2481769	0,09653211	0,09934534	0,171015126
54	0,20908404	0,55753314	0,22797838	0,21115779	0,24464842	-0,03160814	0,07744499	0,308579408
55	0,26968444	0,36787737	0,12605817	0,19943636	0,303728	-0,08760835	0,09135141	0,279575441
56	0,3580922	0,33555377	-0,22034317			3,10550183		-0,10914547

Appendix B

Mathematical Appendix to Chapter 5

This appendix aims to detail some of the intermediate manipulations used for the presentation of the model. We will then explicit here the computation of the balance of payment constraint and the path allowing us to deduce the expressions for the GDP growth rate as the expression for GDP.

B.1 The computation of the balance of payment constraint

Let us first consider $X_{c,t}$ as the total exports of the domestic country:

$$X_{c,t} = (Y_{w,t})^{\alpha_j} z_{c,t}$$

It's growth rate can then be expressed as follows:

$$\frac{\Delta X_{c,t}}{X_{c,t-1}} = \alpha_c \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \frac{\Delta z_{c,t}}{z_{c,t-1}}$$

The same procedure can be applied for imports. Hence starting from

$$M_{c,t} = (Y_{c,t})^{\beta_c}(1 - z_{c,t})$$

It's growth rate can then be expressed as follows:

$$\frac{\Delta M_{c,t}}{M_{c,t-1}} = \beta_c \frac{\Delta Y_{c,t}}{Y_{c,t-1}} + \frac{\Delta(1 - z_{c,t})}{(1 - z_{c,t-1})}$$

Applying some minor manipulation this expression can be re-written as:

$$\frac{\Delta M_{c,t}}{M_{c,t-1}} = \beta_c \frac{\Delta Y_{c,t}}{Y_{c,t-1}} - \frac{\Delta z_{c,t}}{z_{c,t-1}} \frac{z_{c,t-1}}{1 - z_{c,t-1}}$$

Assuming that our economies share the same monetary unit, the balance of payment constraint therefore corresponds to the trade balance. Moreover assuming that the balance of payment has to be satisfied at every time period including the initial one. We can therefore assume that if the latter holds at the initial period, to insure the balance of payment constraint to be satisfied, the growth rate of exports has to equal the growth rate of imports. Hence, the expression for the balance of payment constraint written as:

$$\frac{\Delta M_{c,t}}{M_{c,t-1}} = \frac{\Delta X_{c,t}}{X_{c,t-1}}$$

It can therefore be expressed as follows:

$$\beta_c \frac{\Delta Y_{c,t}}{Y_{c,t-1}} - \frac{\Delta z_{c,t}}{z_{c,t-1}} \frac{z_{c,t-1}}{1 - z_{c,t-1}} = \alpha_c \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \frac{\Delta z_{c,t}}{z_{c,t-1}}$$

B.2 From balance of payment constraint to the expression of GDP

Starting from balance of payment constraint:

$$\beta_c \frac{\Delta Y_{c,t}}{Y_{c,t-1}} - \frac{\Delta z_{c,t}}{z_{c,t-1}} \frac{z_{c,t-1}}{1 - z_{c,t-1}} = \alpha_c \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \frac{\Delta z_{c,t}}{z_{c,t-1}}$$

we can then isolate an expression for the GDP growth rate:

$$\frac{\Delta Y_{c,t}}{Y_{c,t-1}} = \frac{\alpha_c}{\beta_c} \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \frac{1}{\beta_c} \left(1 + \frac{z_{c,t-1}}{1 - z_{c,t-1}}\right) \frac{\Delta z_{c,t}}{z_{c,t-1}}$$

$$\frac{\Delta Y_{c,t}}{Y_{c,t-1}} = \frac{\alpha_c}{\beta_c} \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \frac{1}{\beta_c} \left(\frac{1}{1 - z_{c,t-1}}\right) \frac{\Delta z_{c,t}}{z_{c,t-1}}$$

Given the expression for $z_{c,t}$ we obtain that:

$$\begin{aligned}
z_{c,t} &= \textstyle\sum_i z_{i,c,t} \\
&= \textstyle\sum_i z_{i,c,t-1} \left[1 + \phi \left(\frac{E_{i,c,t}}{\bar{E}_t} - 1\right)\right] \\
&= \textstyle\sum_i z_{i,c,t-1} + \sum_i \phi \left[z_{i,c,t-1} \left(\frac{E_{i,c,t}}{\bar{E}_t} - 1\right)\right] \\
&= z_{c,t-1} + \phi \left(\frac{\sum_i z_{i,c,t-1} E_{i,c,t}}{\bar{E}_t} - z_{c,t-1}\right) \\
&= z_{c,t-1} + z_{c,t-1} \phi \left(\frac{\sum_i \frac{z_{i,c,t-1}}{z_{c,t-1}} E_{i,c,t}}{\bar{E}_t} - 1\right) \\
&= z_{c,t-1} + z_{c,t-1} \phi \left(\frac{E_{c,t}}{\bar{E}_t} - 1\right) \text{ with } E_{c,t} = \textstyle\sum_i \frac{z_{i,c,t-1}}{z_{c,t-1}} E_{i,c,t}
\end{aligned}$$

Hence :

$$\frac{\Delta z_{c,t}}{z_{c,t-1}} = \phi\left(\frac{E_{c,t}}{\bar{E}_t} - 1\right)$$

With minor manipulation we can then obtain the expression for GDP growth rate as given by (6.8):

$$\frac{\Delta Y_{c,t}}{Y_{c,t-1}} = \frac{\alpha_c}{\beta_c}\frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \phi\frac{e_{c,t-1}}{\beta_c}\left(\frac{E_{c,t}}{\bar{E}_t} - 1\right)$$

With

$$e_{c,t-1} = \frac{1}{1 - z_{c,t-1}}$$

We can then deduce the expression for GDP as follows:

$$Y_{c,t} = Y_{c,t-1}\left(1 + \frac{\Delta Y_{c,t}}{Y_{c,t-1}}\right)$$

Replacing the expression for the GDP growth rate as found previously we then obtain the expression for GDP as given by equation (6.9)

$$Y_{c,t} = Y_{c,t-1}\left(1 + \frac{\alpha_c}{\beta_c}\frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \phi\frac{e_{c,t-1}}{\beta_c}\left(\frac{E_{c,t}}{\bar{E}_t} - 1\right)\right)$$

Appendix C

Mathematical Appendix to Chapter 6

This appendix aims to detail some of the intermediate manipulations used for the presentation of the model. We will then explicit here the computation of the balance of payment constraint, the path allowing us to deduce the expressions for the GDP growth rate as the expression for GDP.

C.1 The computation of sectors exports and imports growth rates

Starting from the expression for sector j's exports :

$$X_{j,c,t} = s_{j,w,t}(Y_{w,t})^{\alpha_c} z_{j,c,t}$$

we obtain the following expression for the growth rate of exports in this sector:

$$\frac{\Delta X_{j,c,t}}{X_{j,c,t-1}} = \frac{\Delta s_{j,w,t}}{s_{j,w,t-1}} + \alpha_c \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \frac{\Delta z_{j,c,t}}{z_{j,c,t-1}}$$

Given the expression for $s_{j,w,t}$ as defined in the model we obtain:

$$\frac{\Delta s_{j,w,t}}{s_{j,w,t-1}} = (\epsilon_j - 1) \frac{\Delta Y_{w,t}}{Y_{w,t-1}}$$

Given the expression for $z_{j,c,t}$ we obtain that:

$$\begin{aligned}
&= \sum_i z_{i,j,c,t} \\
&= \sum_i z_{i,j,c,t-1} \left[1 + \phi \left(\frac{E_{i,j,c,t}}{\bar{E}_{j,t}} - 1\right)\right] \\
&= \sum_i z_{i,j,c,t-1} + \sum_i \phi \left[z_{i,j,c,t-1} \left(\frac{E_{i,j,c,t}}{\bar{E}_{j,t}} - 1\right)\right] \\
z_{j,c,t} &= z_{j,c,t-1} + \phi \left(\frac{\sum_i z_{i,j,c,t-1} E_{i,j,c,t}}{\bar{E}_{j,t}} - z_{j,c,t-1}\right) \\
&= z_{j,c,t-1} + z_{j,c,t-1}\phi \left(\frac{\sum_i \frac{z_{i,j,c,t-1}}{z_{j,c,t-1}} E_{i,j,c,t}}{\bar{E}_{j,t}} - 1\right) \\
&= z_{j,c,t-1} + z_{j,c,t-1}\phi \left(\frac{E_{j,c,t}}{\bar{E}_{j,t}} - 1\right) \text{ with } E_{j,c,t} = \sum_i \frac{z_{i,j,c,t-1}}{z_{j,c,t-1}} E_{i,j,c,t}
\end{aligned}$$

Hence :

$$\frac{\Delta z_{j,c,t}}{z_{j,c,t-1}} = \phi \left(\frac{E_{j,c,t}}{\bar{E}_{j,t}} - 1\right)$$

Thus we obtain the following expression for sector j's export growth rate:

$$\frac{\Delta X_{j,c,t}}{X_{j,c,t-1}} = (\alpha_c + \epsilon_j - 1) \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \phi \left(\frac{E_{j,c,t}}{\bar{E}_{j,t}} - 1\right)$$

Symmetrically, we can compute import's growth rate. Starting from the expression for sector j's imports :

$$M_{j,c,t} = s_{j,c,t}(Y_{c,t})^{\beta_c}(1 - z_{j,c,t})$$

we obtain the following expression for the growth rate of exports in this sector:

$$\frac{\Delta M_{j,c,t}}{M_{j,c,t-1}} = \frac{\Delta s_{j,c,t}}{s_{j,c,t-1}} + \beta_c \frac{\Delta Y_{c,t}}{Y_{c,t-1}} + \frac{\Delta(1 - z_{j,c,t})}{(1 - z_{j,c,t-1})}$$

Given the expression for $s_{j,c,t}$ as defined in the model we obtain:

$$\frac{\Delta s_{j,c,t}}{s_{j,w,t-1}} = (\epsilon_j - 1) \frac{\Delta Y_{c,t}}{Y_{c,t-1}}$$

Given the expression for $z_{j,c,t}$ we obtain that:

$$\begin{aligned}
&= \tfrac{1-z_{j,c,t}-(1-z_{j,c,t-1})}{1-z_{j,c,t-1}} \\
&= \tfrac{z_{j,c,t-1}-z_{j,c,t}}{1-z_{j,c,t-1}} \\
\frac{\Delta(1-z_{j,c,t})}{1-z_{j,c,t-1}} &= \tfrac{z_{j,c,t-1}-\left[z_{j,c,t-1}+z_{j,c,t-1}\phi\left(\frac{E_{j,c,t}}{\bar{E}_{j,t}}-1\right)\right]}{1-z_{j,c,t-1}} \\
&= -\tfrac{z_{j,c,t-1}}{1-z_{j,c,t-1}}\phi\left(\tfrac{E_{j,c,t}}{\bar{E}_{j,t}}-1\right) \\
&= -b_{j,c,t-1}\phi\left(\tfrac{E_{j,c,t}}{\bar{E}_{j,t}}-1\right) \text{ with } b_{j,c,t-1} = \tfrac{z_{j,c,t-1}}{1-z_{j,c,t-1}}
\end{aligned}$$

Thus we obtain the following expression for sector j's import growth rate:

$$\frac{\Delta M_{j,c,t}}{M_{j,c,t-1}} = (\beta_c + \epsilon_j - 1)\frac{\Delta Y_{c,t}}{Y_{c,t-1}} - b_{j,c,t-1}\phi\left(\frac{E_{j,c,t}}{\bar{E}_{j,t}} - 1\right)$$

C.2 The computation of the balance of payment constraint

Let us first consider $X_{c,t}$ as the total exports of the domestic economy. It can be expressed as the sum of sectoral exports:

$$X_{c,t} = \sum_j p_{j,c,t}X_{j,c,t}$$

It's growth rate can then be expressed as follows:

$$\frac{\Delta X_{c,t}}{X_{c,t-1}} = \frac{\Delta\left(\sum_j p_{j,c,t}X_{j,c,t}\right)}{X_{c,t-1}} = \frac{\sum_j \Delta\left(p_{j,c,t}X_{j,c,t}\right)}{\sum_j p_{j,c,t-1}X_{j,c,t-1}} = \frac{\sum_j X_{j,c,t-1}\Delta p_{j,c,t} + p_{j,c,t-1}\Delta X_{j,c,t}}{\sum_j p_{j,c,t-1}X_{j,c,t-1}}$$

Through some minor manipulation $\frac{\Delta X_{c,t}}{X_{c,t-1}}$ can be expressed as follows:

$$\frac{\Delta X_{c,t}}{X_{c,t-1}} = \sum_j \frac{\Delta p_{j,c,t}}{p_{j,c,t-1}}\frac{p_{j,c,t-1}X_{j,c,t-1}}{\sum_j p_{j,c,t-1}X_{j,c,t-1}} + \sum_j \frac{\Delta X_{j,c,t}}{X_{j,c,t-1}}\frac{p_{j,c,t-1}X_{j,c,t-1}}{\sum_j p_{j,c,t-1}X_{j,c,t-1}}$$

Given the expression of $X_{j,c,t}$ as defined in the model:

$$X_{j,c,t} = s_{j,w,t}(Y_{w,t})^{\alpha}z_{j,c,t}$$

we can then simplify the expression for $\frac{p_{j,c,t-1}X_{j,c,t-1}}{\sum_j p_{j,c,t-1}X_{j,c,t-1}}$ as follows:

$$\begin{aligned}
& = \frac{p_{j,c,t-1}s_{j,w,t-1}(Y_{w,t-1})^{\alpha}z_{j,c,t-1}}{\sum_j p_{j,c,t-1}s_{j,w,t-1}(Y_{w,t-1})^{\alpha}z_{j,c,t-1}} \\
\frac{p_{j,c,t-1}X_{j,c,t-1}}{\sum_j p_{j,c,t-1}X_{j,c,t-1}} & = \frac{(Y_{w,t-1})^{\alpha}p_{j,c,t-1}s_{j,w,t-1}z_{j,c,t-1}}{(Y_{w,t-1})^{\alpha}\sum_j p_{j,c,t-1}s_{j,w,t-1}z_{j,c,t-1}} \\
& = \frac{p_{j,c,t-1}s_{j,w,t-1}z_{j,c,t-1}}{\sum_j p_{j,c,t-1}s_{j,w,t-1}z_{j,c,t-1}} = e_{j,c,t-1}
\end{aligned}$$

The same procedure can be applied for imports. Hence starting from

$$M_{c,t} = \sum_j p^m_{j,c,t}M_{j,c,t}$$

One can easily show that:

$$\frac{\Delta M_{c,t}}{M_{c,t-1}} = \sum_j \frac{p^m_{j,c,t-1}M_{j,c,t-1}}{\sum_j p^m_{j,c,t-1}M_{j,c,t-1}}\frac{\Delta M_{j,c,t}}{M_{j,c,t-1}} + \sum_j \frac{p^m_{j,c,t-1}M_{j,c,t-1}}{\sum_j p^m_{j,c,t-1}M_{j,c,t-1}}\frac{\Delta p^m_{j,c,t}}{p^m_{j,c,t-1}}$$

Given the expression of $M_{jc,,t}$ as defined in the model:

$$M_{j,c,t} = s_{j,c,t}(Y_{c,t})^{\beta}(1 - z_{j,c,t})$$

we can then deduce that:

$$\frac{p^m_{j,c,t-1}M_{j,c,t-1}}{\sum_j p^m_{j,c,t-1}M_{j,c,t-1}} = \frac{p^m_{j,c,t-1}s_{j,c,t-1}(1 - z_{j,c,t-1})}{\sum_j p^m_{j,c,t-1}s_{j,c,t-1}(1 - z_{j,c,t-1})} = i_{j,c,t-1}$$

Hence, the expression for the balance of payment constraint written as:

$$\frac{\Delta X_{c,t}}{X_{c,t-1}} = \frac{\Delta M_{c,t}}{M_{c,t-1}}$$

can be expressed as follows:

$$\sum_j i_{j,c,t-1}\frac{\Delta M_{j,c,t}}{M_{j,c,t-1}} + \sum_j i_{j,c,t-1}\frac{\Delta p^m_{j,c,t}}{p^m_{j,c,t-1}} = \sum_j e_{j,c,t-1}\frac{\Delta X_{j,c,t}}{X_{j,c,t-1}} + \sum_j e_{j,c,t-1}\frac{\Delta p_{j,c,t}}{p_{j,c,t-1}}$$

C.3 From balance of payment constraint to the expression of GDP growth rate

Starting from balance of payment constraint:

$$\sum_j i_{j,c,t-1}\frac{\Delta M_{j,c,t}}{M_{j,c,t-1}} + \sum_j i_{j,c,t-1}\frac{\Delta p^m_{j,c,t}}{p^m_{j,c,t-1}} = \sum_j e_{j,c,t-1}\frac{\Delta X_{j,c,t}}{X_{j,c,t-1}} + \sum_j e_{j,c,t-1}\frac{\Delta p_{j,c,t}}{p_{j,c,t-1}}$$

We can substitute for each sectors, imports and exports growth rates by the expressions defined above in the paper. We then obtain the following expression for the balance of payment constraint:

$$\sum_j i_{j,c,t-1}\left[(\beta_c+\epsilon_j-1)\frac{\Delta Y_{c,t}}{Y_{c,t-1}}-b_{j,c,t-1}\phi\left(\frac{E_{j,c,t}}{\bar{E}_{j,t}}-1\right)\right]+\sum_j i_{j,c,t-1}\frac{\Delta p^m_{j,c,t}}{p^m_{j,c,t-1}}$$
$$=\sum_j e_{j,c,t-1}\left[(\alpha_c+\epsilon_j-1)\frac{\Delta Y_{w,t}}{Y_{w,t-1}}+\phi\left(\frac{E_{j,c,t}}{\bar{E}_{j,t}}-1\right)\right]+\sum_j e_{j,c,t-1}\frac{\Delta p_{j,c,t}}{p_{j,c,t-1}}$$

Given that the sum among j of $i_{j,c,t-1}$ and $e_{j,c,t-1}$ equal one, hence the previous expression can be re-written as follows:

$$\left(\beta_c+\sum_j i_{j,c,t-1}\epsilon_j-1\right)\frac{\Delta Y_{c,t}}{Y_{c,t-1}}-\phi\sum_j i_{j,c,t-1}b_{j,c,t-1}\left(\frac{E_{j,c,t}}{\bar{E}_{j,t}}-1\right)+\sum_j i_{j,c,t-1}\frac{\Delta p^m_{j,c,t}}{p^m_{j,c,t-1}}$$

$$=\left(\alpha_c+\sum_j e_{j,c,t-1}\epsilon_j-1\right)\frac{\Delta Y_{w,t}}{Y_{w,t-1}}+\phi\sum_j e_{j,c,t-1}\left(\frac{E_{j,c,t}}{\bar{E}_{j,t}}-1\right)+\sum_j e_{j,c,t-1}\frac{\Delta p_{j,c,t}}{p_{j,c,t-1}}$$

Starting from this expression of the balance of payment constraint, we can then isolate an expression for the GDP growth rate:

$$\frac{\Delta Y_{c,t}}{Y_{c,t-1}}=\gamma_{c,t-1}\frac{\Delta Y_{w,t}}{Y_{w,t-1}}+\lambda_{c,t-1}\phi\left[\sum_j \theta_{j,c,t-1}\left(\frac{E_{j,c,t}}{\bar{E}_{j,t}}-1\right)\right]+\lambda_{c,t-1}\sum_j \kappa_{j,c,t-1}$$

With

$$\gamma_{c,t-1}=\frac{\alpha_c+\sum_j e_{j,c,t-1}\varepsilon_j-1}{\beta+\sum_j i_{j,c,t-1}\varepsilon_j-1}$$
$$\lambda_{c,t-1}=\frac{1}{\beta+\sum_j i_{j,c,t-1}\varepsilon_j-1}$$
$$\theta_{j,c,t-1}=e_{j,c,t-1}+i_{j,c,t-1}b_{j,c,t-1}$$
$$\kappa_{j,c,t-1}=e_{j,c,t-1}\frac{\Delta p_{j,c,t}}{p_{j,c,t-1}}-i_{j,c,t-1}\frac{\Delta p^m_{j,c,t}}{p^m_{j,c,t-1}}$$

Appendix D

Mathematical Appendix to Chapter 7

This appendix aims to detail some of the intermediate manipulations used for the presentation of the model. This appendix is organised as follows: First we quickly prove that the share of sector's demand always sum to one. Second we develop the computation of the expression for GDP starting from the aggregation of sector's gross product.

D.1 Dynamics of sector's share

The shares of income devoted to the consumption of each sectors is computed as described in equation 7.3:

$$s_{j,c,t} = s_{j,c,t-1}\left(1 + \frac{\partial s_{j,c,t}}{\partial G_{c,t}}\frac{\Delta G_{c,t}}{G_{c,t-1}}\right)$$

with

$$\frac{\partial s_{j,c,t}}{\partial G_{c,t}} = s_{j,c,t-1}\sum_{\bar{j}} b_{\bar{j}j}(s_{\bar{j},c,t-1} - \bar{s}_{\bar{j}}) - (s_{j,c,t-1} - \bar{s}_j)\sum_{\bar{j}} b_{j\bar{j}} s_{\bar{j},c,t-1}$$

Hence, the variation in share is the following:

$$\frac{s_{j,c,t} - s_{j,c,t-1}}{s_{j,c,t-1}} = \frac{\partial s_{j,c,t}}{\partial G_{c,t}}\frac{\Delta G_{c,t}}{G_{c,t-1}}$$

Summing these variations we obtain:

$$\sum_j \frac{s_{j,c,t} - s_{j,c,t-1}}{s_{j,c,t-1}} = \frac{\Delta G_{c,t}}{G_{c,t-1}}\sum_j \frac{\partial s_{j,c,t}}{\partial G_{c,t}}$$

Given:

$$\sum_j \frac{\partial s_{j,c,t}}{\partial G_{c,t}} = \sum_j \left(s_{j,c,t-1} \sum_{\bar{j}} b_{\bar{j}j}(s_{\bar{j},c,t-1} - \bar{s}_{\bar{j}}) - (s_{j,c,t-1} - \bar{s}_j) \sum_{\bar{j}} b_{j\bar{j}} s_{\bar{j},c,t-1} \right)$$

$$= \sum_j \sum_{\bar{j}} b_{\bar{j}j} s_{j,c,t-1}(s_{\bar{j},c,t-1} - \bar{s}_{\bar{j}}) - \sum_j \sum_{\bar{j}} b_{j\bar{j}} s_{\bar{j},c,t-1}(s_{j,c,t-1} - \bar{s}_j)$$

$$= \begin{array}{l} b_{2,1}s_{1,c,t-1}(s_{2,c,t-1} - \bar{s}_2) + ... + b_{J,1}s_{1,c,t-1}(s_{J,c,t-1} - \bar{s}_J) + ... \\ ... + b_{1,J}s_{J,c,t-1}(s_{1,c,t-1} - \bar{s}_1) + ... + b_{J-1,J}s_{J,c,t-1}(s_{J-1,c,t-1} - \bar{s}_{J-1}) \\ -b_{1,2}s_{2,c,t-1}(s_{1,c,t-1} - \bar{s}_1) - ... - b_{1,J}s_{J,c,t-1}(s_{1,c,t-1} - \bar{s}_1) - ... \\ ... - b_{J,1}s_{1,c,t-1}(s_{J,c,t-1} - \bar{s}_J) - ... - b_{J,J-1}s_{J-1,c,t-1}(s_{J,c,t-1} - \bar{s}_J) \end{array}$$

$$= \begin{array}{l} (s_{1,c,t-1} - \bar{s}_1)(b_{1,2}s_{2,c,t-1} + ... + b_{1,J}s_{J,c,t-1} - b_{1,2}s_{2,c,t-1} - ... - b_{1,J}s_{J,c,t-1}) + ... \\ ... + (s_{J,c,t-1} - \bar{s}_J)(b_{J,1}s_{1,c,t-1} + ... + b_{J,J-1}s_{J-1,c,t-1} - b_{J,1}s_{1,c,t-1} - ... - b_{J,J-1}s_{J-1,c,t-1}) \end{array}$$

Hence:

$$\sum_j \frac{\partial s_{j,c,t}}{\partial G_{c,t}} = 0$$

therefore:

$$\sum_j \frac{s_{j,c,t} - s_{j,c,t-1}}{s_{j,c,t-1}} = 0$$

The variations in shares always compensate, therefore if the initial shares sum to one, the shares always sum to one.

D.2 Defining aggregate product.

We detail here the computation of the expression for GDP as the aggregate of sectors gross product. Starting from the internal and external components of sectoral demand defined as follows:

$$C_{j,c,t} = s_{j,c,t-1} Y_{c,t} z_{j,c,t}$$

$$X_{j,c,t} = z_{j,c,t} \sum_{\bar{c}} e_{\bar{c},t-1} s_{j,\bar{c},t-1} Y_{\bar{c},t-1}(1 - z_{j,\bar{c},t})$$

we compute the sectors' demand as follows:

$$D_{j,c,t} = \frac{C_{j,c,t}}{p_{j,c,t}} + \frac{X_{j,c,t}}{e_{c,t-1} p_{j,c,t}}$$

Replacing consumption and exports by their formal expression we obtain the following expression for sectors' demands:

$$D_{j,c,t} = \frac{1}{p_{j,c,t}} s_{j,c,t-1} Y_{c,t} z_{j,c,t} + \frac{1}{p_{j,c,t}} z_{j,c,t} \sum_{\bar{c}} \frac{e_{\bar{c},t-1}}{e_{c,t-1}} s_{j,\bar{c},t-1}(1 - z_{j,\bar{c},t}) Y_{\bar{c},t-1}$$

We assume that the production level of each sector is defined by the demand level. The GDP level being the aggregation of the sectoral products, the GDP level corresponds to the aggregation of sectors demands:

$$Y_{c,t} \equiv \sum_j p_{j,c,t} Q_{j,c,t} = \sum_j p_{j,c,t} D_{j,c,t}$$

Replacing the sectors demand by the expression previously found we obtain the following expression for GDP:

$$Y_{c,t} = \sum_j s_{j,c,t-1} Y_{c,t} z_{j,c,t} + z_{j,c,t} \sum_{\bar{c}} \frac{e_{\bar{c},t-1}}{e_{c,t-1}} s_{j,\bar{c},t-1}(1 - z_{j,\bar{c},t}) Y_{\bar{c},t-1}$$

$$Y_{c,t} = Y_{c,t}(\sum_j s_{j,c,t-1} z_{j,c,t}) + \sum_j z_{j,c,t} \sum_{\bar{c}} \frac{e_{\bar{c},t-1}}{e_{c,t-1}} s_{j,\bar{c},t-1}(1 - z_{j,\bar{c},t}) Y_{\bar{c},t-1}$$

Isolating the GDP on the left side of the expression we then obtain the following expression for GDP depending on the external component of demand. The value of the multiplier that links GDP to exports is defined by the sectoral structure of the economie:

$$Y_{c,t} = \frac{1}{1 - \sum_j s_{j,c,t-1} z_{j,c,t}} \sum_j z_{j,c,t} \sum_{\bar{c}} \frac{e_{\bar{c},t-1}}{e_{c,t-1}} s_{j,\bar{c},t-1}(1 - z_{j,\bar{c},t}) Y_{\bar{c},t-1}$$

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