CAIRN.INFO
Chercher, repérer, avancer.

CUMULATIVE CAUSATION AND EVOLUTIONARY MICRO-FOUNDED TECHNICAL CHANGE

On the Determinants of Growth rate Differences

Patrick Llerena et André Lorentz

Presses de Sciences Po | *Revue économique*

2004/6 - Vol. 55
pages 1191 à 1214

ISSN 0035-2764

Article disponible en ligne à l'adresse:

----

http://www.cairn.info/revue-economique-2004-6-page-1191.htm

Pour citer cet article :

Llerena Patrick et Lorentz André, « Cumulative Causation and Evolutionary Micro-Founded Technical Change » On the Determinants of Growth rate Differences,
Revue économique, 2004/6 Vol. 55, p. 1191-1214. DOI : 10.3917/reco.556.1191

Distribution électronique Cairn.info pour Presses de Sciences Po.

© Presses de Sciences Po. Tous droits réservés pour tous pays.

La reproduction ou représentation de cet article, notamment par photocopie, n'est autorisée que dans les limites des conditions générales d'utilisation du site ou, le cas échéant, des conditions générales de la licence souscrite par votre établissement. Toute autre reproduction ou représentation, en tout ou partie, sous quelque forme et de quelque manière que ce soit, est interdite sauf accord préalable et écrit de l'éditeur, en dehors des cas prévus par la législation en vigueur en France. Il est précisé que son stockage dans une base de données est également interdit.

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

Cumulative Causation and Evolutionary Micro-Founded Technical Change

On the Determinants of Growth rate Differences

Patrick Llerena*
André Lorentz**

We develop in this paper an alternative approach to the New Growth Theory to analyse growth rate differences among integrated economies. The model presented here considers economic growth as a disequilibrium process. It introduces in a cumulative causation framework, micro-founded process of technical change taking into account elements rooted in evolutionary and Neo-Austrian literature. We then attempt to open the "Kaldor-Verdoorn law black-box" using a microlevel modelling of industrial dynamics.

We use this framework to study the nature and sources of growth rate differences among economies, focusing on the effect of some macroeconomic parameters and of some technological parameters. If the results remain broadly in Kaldorian lines, this framework allows for more subtle patterns of growth rate difference.

CROISSANCE CUMULATIVE ET MODÉLISATION ÉVOLUTIONNAIRE DU CHANGEMENT TECHNIQUE : LES SOURCES DE DIVERGENCES DE TAUX DE CROISSANCE

Cet article développe une approche alternative à l'analyse des différences en taux de croissance entre économies telle que proposée par les Nouvelles Théories de la Croissance. Notre analyse se place dans une approche de la croissance comme un processus en déséquilibre. Ce dernier repose sur le cadre développé dans la théorie dite de la croissance cumulative pour laquelle le changement technique résulte de processus microéconomiques inspirés par les approches évolutionnistes et néo-autrichienne. En ce sens, nous remplaçons la traditionnelle loi de Kaldor-Verdoorn par une modélisation explicite de la dynamique industrielle.

À l'aide de ce modèle, nous cherchons à identifier les sources de divergences entre économies liées notamment à certains paramètres macroéconomiques et technologiques. Ceci nous permettra de mettre en évidence différents régimes de divergence, nuançant ainsi certains résultats trouvés dans la littérature.

JEL Classification: O41, O30, F43

* Bureau d'économie théorique et appliquée, Université Louis Pasteur, Strasbourg. Email: pllerena@cournot.ustrasbg.fr

** Bureau d'économie théorique et appliquée, Université Louis Pasteur, Strasbourg, and Laboratorio di Economia e Management, Scuola Superiore Sant'Anna, Pisa. Email: lorentz@cournot.u-strasbg.fr

Authors would like to thank M. Anoufriev, C. Castaldi, G. Dosi, G. Fagiolo and R. Gabriele for their precious comments on this work. Part of the research has been supported by the EU, under the research programme "MACROTEC" (HPSE CT 1999 00014), and did especially benefit from the discussions and comments from Nick Von Tunzelmann (SPRU). All usual disclaimers should nevertheless apply.

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

INTRODUCTION

The literature on economic growth is dominated since the 90s by the developments of the New Growth Theory (NGT), also called "Endogenous growth theory". It is at least a good indicator of the relevance of two propositions:

– to explain why economies growth is again a relevant and still an open question in economics;

– the factors of growth should be "endogenous" to be acceptable; that economist should go beyond the simplified version of the Solow canonical model, with exogenous technical changes.

But at the same time, this literature did hide a long tradition of research which could certainly give some alternative explanations to the persistence of phenomena such as growth rate divergence among countries or regions. Among these potential alternatives there are at least three which are worth mentioning in the context of our paper: the Kaldorian approaches of a cumulative causation, the evolutionary perspectives of diversity and selection and the Austrian view of the decision sequences and path dependency. Even if it is usually considered that the alternative approaches are too heterogeneous to be built into an integrated and coherent framework; they have at least some common features which could justify a comprehensive complementarity. Contrary to the NGT, all three approaches economise in terms of degree of rationality of economic agents, escape from technologies being dealt with as information, and introduce innovation as a process of knowledge creation, and finally consider that "history matters" *i.e.* the focus should be rather in the "out of equilibrium" processes than on the equilibrium characteristics and existence.

The purpose of this paper is not to propose a "re-constructed" and "integrated" alternative theory of growth[1], but to build a simple model, integrating some of the main features of these alternative theories in order to show their complementarity in explaining some classical "stylised phenomena". Our focus will be in this paper the growth rate divergence among integrated economies.

The main aspect of Kaldorian approaches (Kaldor (1972, 1981); Dixon and Thirlwall (1975); Verspagen (2002)) is essentially based on two principles: A demand-driven growth and a cumulative causation. In this framework, Kaldor's explanation of growth rate is the result of two "interrelated mechanisms": 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. 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 can be described as follows. The rule for prices is a mark-up over unit labour cost. The growth of productivity based on the growth of output would reduce this unit labour cost, then prices, and thus increase the country's competitiveness. This increasing competitiveness would lead to increasing exports, themselves leading to a higher

1. This issue is considered in Llerena and Lorentz (2004).

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

growth rate. Thus for a given initial competitiveness advantage, growth rates will tend, through the circular and cumulative mechanisms, to be maintained or increased over time. This implies also that initial conditions strongly dictate the growth process, providing for virtuous cumulative mechanisms (as described previously) rather than a vicious one where growth could never be self-sustained and so cumulative processes could never start.

The major mechanisms driving the Kaldorian cumulative growth process can be summarised as follows: the Verdoorn law allows self-sustained growth, dynamic increasing returns allow cumulativeness of the growth process, and finally initial conditions define this process as a path-dependent process, where initial competitiveness differences tend to increase rather than decrease.

One of the main drawbacks of the approach is the "Kaldor-Verdoorn black box". Our paper is to 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 (through R&D expenditure by firms, innovation and integration into new investments), in order to endogenise the evolution of productivity and so to close the model with a micro-founded alternative to the Kaldor-Verdoorn law.

Finally we have some Austrian flavour in our model, because we explicitly constraint the decision process at the firm level to a given sequence: investment and R&D expenditure are financially constrained by previous profits. The liquidity constraint is essential as a device to structure both the ongoing processes: selection and innovation.

Only few attempts exist in the literature to merge these approaches, the main one being by Verspagen (1993, 2002). Our contribution is principally to add a fully specified model, as a first step for further developments. In particular we wish to differentiate the impact of macro diversity from technological diversity among countries in terms of divergence-convergence of growth rate.

Our model 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"[1]. 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 3, by the development both of the main results and of their interpretations.

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

1. León-Ledesma (2000).

Revue économique — vol. 55, N° 6, novembre 2004, p. 1191-1214

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

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.[1] 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.

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.[2] 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[3] j is given by:

$$X_{j,t} = (Y_{w,t})^{\alpha_j} z_{j,t} \tag{1}$$

1. Assuming then neither trade limitations nor barriers to access foreign markets.
2. We assume here that no external debt among member countries is allowed.
3. Note that the subscript j always reefers to an economy, while the subscript i refers to a firm. We suppose that the model counts J economies each of them counts I firms. Hence a variable with the subscripts "j, i" concerns the firm i based in the country j.

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

where $Y_{w,t}$ represents the GDP of the rest of the world[1], $z_{j,t}$ represents the market share of the economy, on the international markets and α_j income 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 $z_{i,j,t}$):

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

Each firm's market share is defined through a replicator dynamics[2], a function of a firm's relative competitiveness. Hence the market share of each firm will be computed as follows:

$$z_{i,j,t} = z_{i,j,t-1}\left(1+\phi\left(\frac{E_{i,j,t}}{\bar{E}_t}-1\right)\right) \tag{2}$$

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

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

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

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

The parameter $\phi \in [0\,;1]$ mesures 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:

$$M_{j,t} = (Y_{j,t})^{\beta_j}(1-z_{j,t}). \tag{3}$$

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

1. 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.

2. For a comprehensive view on the use of the replicator dynamics in evolutionary economics see Metcalfe (1998).

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

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 *j*'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:

$$\frac{\Delta M_{j,t}}{M_{j,t-1}} = \frac{\Delta X_{j,t}}{X_{j,t-1}} \tag{4}$$

with:

$$\frac{\Delta X_{j,t}}{X_{j,t-1}} = \alpha_j \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \frac{\Delta z_{j,t}}{z_{j,t-1}} \tag{5}$$

$$\frac{\Delta M_{j,t}}{M_{j,t-1}} = \beta \frac{\Delta Y_{j,t}}{Y_{j,t-1}} - \frac{z_{j,t-1}}{1 - z_{j,t-1}} \frac{\Delta z_{j,t}}{z_{j,t-1}} \tag{6}$$

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:

$$\frac{\Delta Y_{j,t}}{Y_{j,t-1}} = \frac{\alpha_j}{\beta_j} \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \frac{e_{j,t-1}}{\beta_j} \frac{\Delta z_{j,t}}{z_{j,t-1}} \tag{7}$$

with $e_{j,t-1} = \dfrac{1}{1 - z_{j,t-1}}$.

The growth rate of market shares can be deduced from equation (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:

$$\frac{\Delta Y_{j,t}}{Y_{j,t-1}} = \frac{\alpha_j}{\beta_j} \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \phi \frac{e_{j,t-1}}{\beta_j} \left(\frac{E_{j,t}}{\bar{E}_t} - 1 \right). \tag{8}$$

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:

$$Y_{j,t} = Y_{j,t-1} \left[1 + \frac{\alpha_j}{\beta_j} \frac{\Delta Y_{w,t}}{Y_{w,t-1}} + \phi \frac{e_{j,t-1}}{\beta_j} \left(\frac{E_{j,t}}{\bar{E}_t} - 1 \right) \right]. \tag{9}$$

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.

Revue économique — vol. 55, N° 6, novembre 2004, p. 1191-1214

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

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:

$$w_{j,t} = w_{j,t-1}\left(1+\gamma\,\frac{\Delta \mathrm{A}_{j,t}}{\mathrm{A}_{j,t-1}}\right). \tag{10}$$

$\mathrm{A}_{j,t}$ represents the average labour productivity level of the economy j 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.

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 evolutionary literature on the modelling of industrial dynamics.[1] 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. This second stage is financed by profits, and then directly subject to 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 based on "industrial dynamics".

Revue économique — vol. 55, N° 6, novembre 2004, p. 1191-1214

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

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:

$$Y_{i,j,t} = A_{i,j,t-1} L(i, j, t) \tag{11}$$

where $Y_{i,j,t}$ is the output of firm i, producing in country j at time t. $A_{i,j,t-1}$ represents labour productivity and $L_{i,j,t}$ 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:

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

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

$$A_{i,j,t} = \frac{I_{i,j,t} a_{i,j,t-1}}{\sum_{\tau}^{t} I_{i,j,\tau}} + \frac{\sum_{\tau=1}^{t-1} I_{i,j,\tau}}{\sum_{\tau=1}^{t} I_{i,j,\tau}} A_{i,j,t-1} \tag{12}$$

where $a_{i,j,t-1}$ represents the labour productivity embodied in the capital good developed by i during period $t-1$. $I_{i,j,t}$ 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:

$$p_{i,j,t} = (1 + \mu_j) \frac{w_{j,t-1}}{A_{i,j,t-1}} \tag{13}$$

where $p_{i,j,t}$ represents the price set by firm i at time t, μ_j the mark-up coefficient and $w_{j,t-1}$ 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 will then be computed as follows:

$$\begin{aligned} \Pi_{i,j,t} &= p_{i,j,t} Y_{i,j,t} - w_{j,t-1} L_{i,j,t} \\ \Pi_{i,j,t} &= \mu_j \frac{w_{j,t-1}}{A_{i,j,t-1}} Y_{i,j,t} \end{aligned} \tag{14}$$

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

Revue économique — vol. 55, N° 6, novembre 2004, p. 1191-1214

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

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 $\iota_{i,j}$ 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:

$$\mathrm{I}_{i,j,t} = \min\{\iota_{i,j}\mathrm{Y}_{i,j,t}\,;\,\Pi_{i,j,t}\}\,. \tag{15}$$

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".[1] Investments in R&D are a share $\rho_{i,j}$ of their sales. R&D investment will correspond to the hiring of workers assigned to the research activity:

$$\mathrm{R}_{i,j,t} = \frac{1}{w_{j,t-1}}\min\{\rho_{i,j}\mathrm{Y}_{i,j,t}\,;\,\Pi_{i,j,t} - \mathrm{I}_{i,j,t}\} \tag{16}$$

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 $\left[0\,;\,\frac{\mathrm{R}_{i,j,t}}{\mathrm{Y}_{i,j,t}}\right]$, the R&D is successful.

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

$$a_{i,j,t} = \max\{a_{i,j,t-1} + \epsilon_{i,j,t}\,;\,a_{i,j,t}\} \tag{17}$$

$$\epsilon_{i,j,t} \sim \mathrm{N}(0\,;\,\sigma_{i,j,t}) \tag{18}$$

$$\text{with}\begin{cases}\sigma_{i,j,t} = \sigma_j & \text{if the firm is an innovator}\\ \sigma_{i,j,t} = \chi(\bar{a}_t - a_{i,j,t}) & \text{if the firme is an imitator}\end{cases} \tag{19}$$

1. See Amendola and Gaffard (1998), p. 126.

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

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

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

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.

Firms exit the market if their market share is lower then $\bar{z}_j$. They are replaced by firms characterised by the average values on the technological variables within the economy of these exiting firms and a market share equal to $\bar{z}_j$. 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.[1]

GROWTH RATE DIFFERENCE AMONG INTEGRATED ECONOMIES: SOME 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[2]. 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 appendix.

1. This proportion is set to 50% for the simulations.

2. 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.

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

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

– $\bar{\sigma}_j$ defines the level of technological opportunities for the innovators. The higher $\bar{\sigma}_j$, 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_j defines the absorptive capacities of imitating firms. The higher χ_j, 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. Differences in GDP and productivity growth rates are measured using the coefficient of variation of these variables among the 5 economies.

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

Selection and Growth Rates Differences

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 1 and 2.

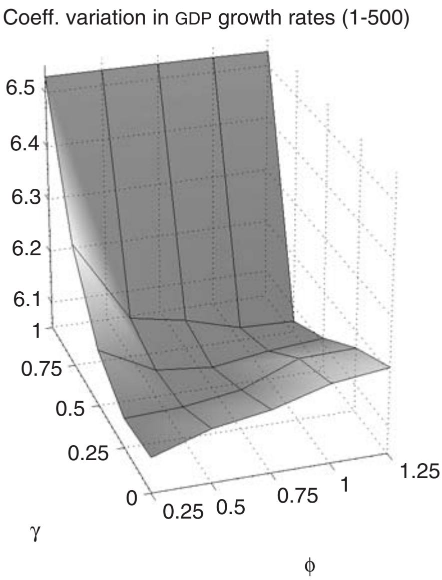


Figure 1. *Differnces in GDP growth rates with canges in* γ *and* ϕ

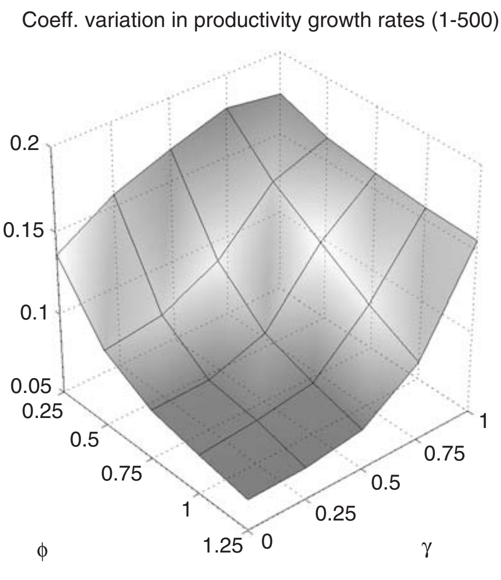


Figure 2. *Differences in productivity growth rates with changes in* γ *and* ϕ

Figure 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

Revue économique — vol. 55, N° 6, novembre 2004, p. 1191-1214

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

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 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 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.

Demand Characteristics and Growth Rate Differences

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

RESULT 1. *Increasing the heterogeneity in income elasticity to exports α_j significantly increases the differences in GDP growth rates essentially by affecting the trade multiplier.*

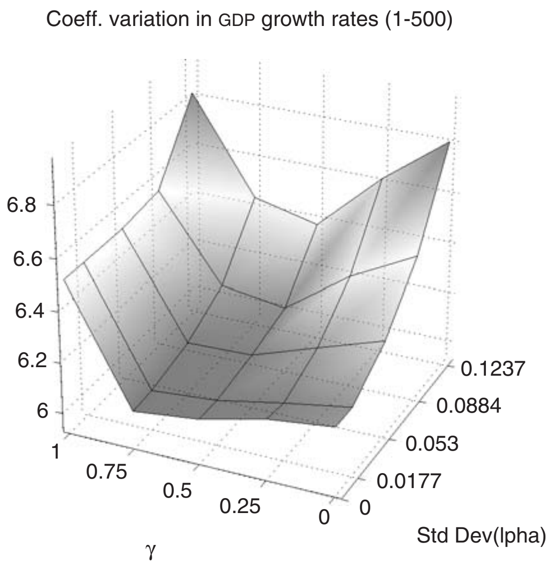


Figure 3. *Differences in GDP growth rates with heterogeneous α_j and changes in γ*

This effect on growth rate difference is perfectly predictable. It results from the trade multiplier component of the model. Heterogeneity in income elasticity

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

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.

RESULT 2. *Heterogeneity in demand parameters generates patterns of sustained growth rate difference without generating vicious circles.*

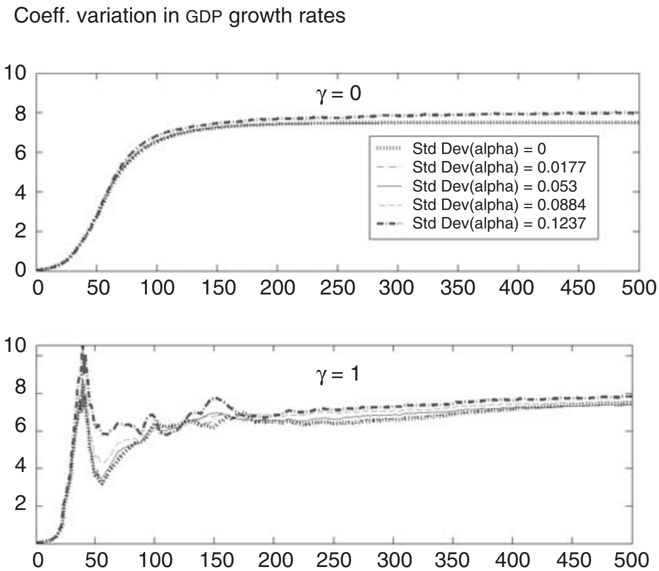
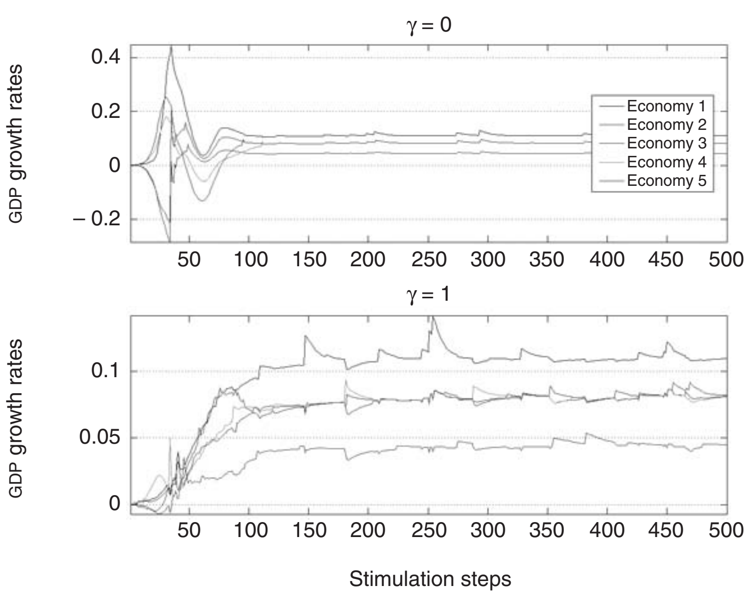


Figure 4. *Differences in GDP growth rates with heterogeneous α_j*

Figure 5. *GDP growth rates with heterogeneous α_j*



Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

As depicted in Figure 4, these difference in GDP growth rates are permanent. The sustainability of this differences is principally due to the effect on the trade multiplier. As depicted in Figure 5, in this example, economies grow parallel to each others at different rates, without the emergence of a dominant economy.

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 6 and Figure 7).

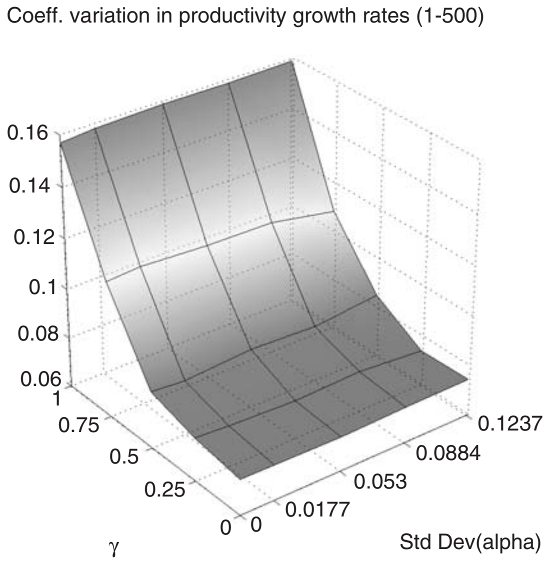


Figure 6. *Differences in productivity growth rates heterogeneous α_j and changes in γ*

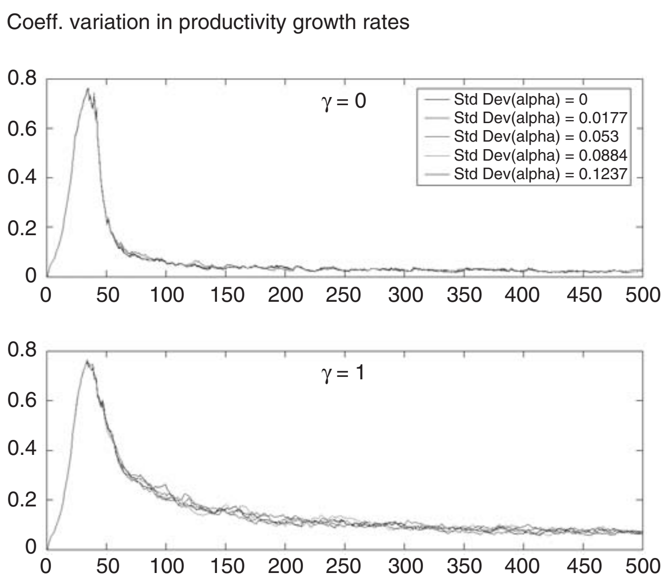
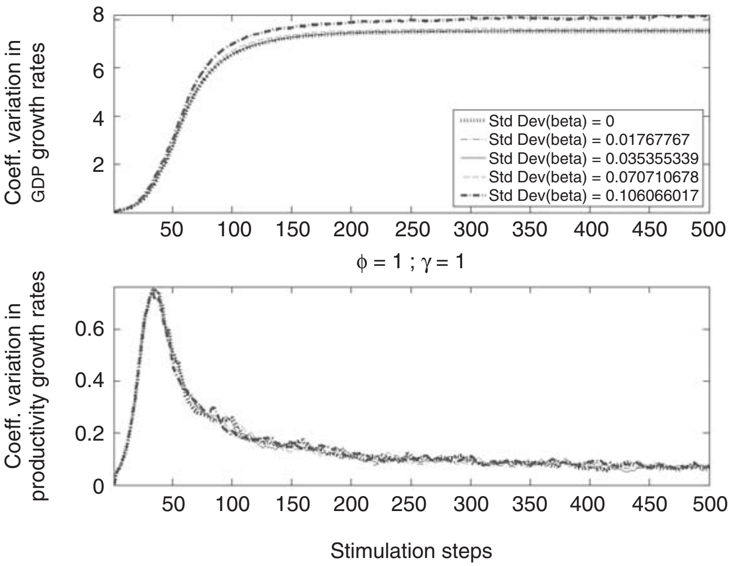


Figure 7. *Differences in productivity growth rates with heterogeneous α_j*

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

Similar patterns emerge when introducing heterogeneity in β_j, as presented in Figure 8.

Figure 8. *Differences in GDP and productivity growth rates with heterogeneous* β_j



To summarise heterogeneity in demand characteristics generates significant differences in growth rates but is not sufficient to generate significant differences in technologies among economies. In this case divergence is not induced by or coupled with the collapsing of economies nor the existence of vicious circles.

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 ($\bar{\sigma}_j$) and absorptive capacities (χ_j), assuming that the economies are initially identical (*i.e.* in terms of initial conditions).

RESULT 3. *Increasing heterogeneity in technological opportunity parameter* ($\bar{\sigma}_j$)*, significantly increases growth rate difference among economies for low values of* γ.

Figure 9 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.

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

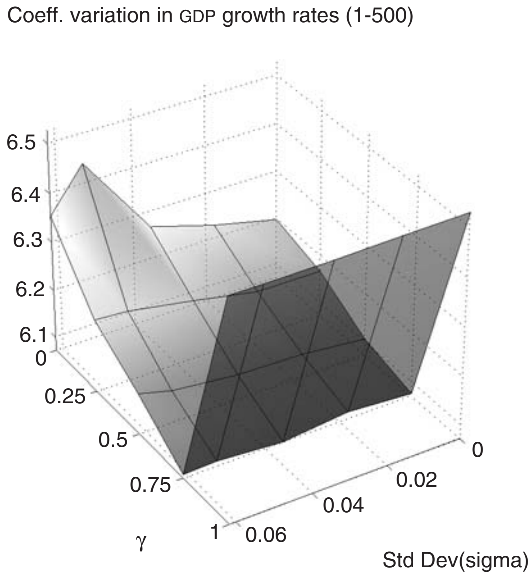


Figure 9. *Differences in GDP growth rates with heterogeneous $\bar{\sigma}_j$ and changes in γ*

RESULT 4. *Heterogeneity in technological opportunity parameter transitorily affect growth rate difference among economies.*

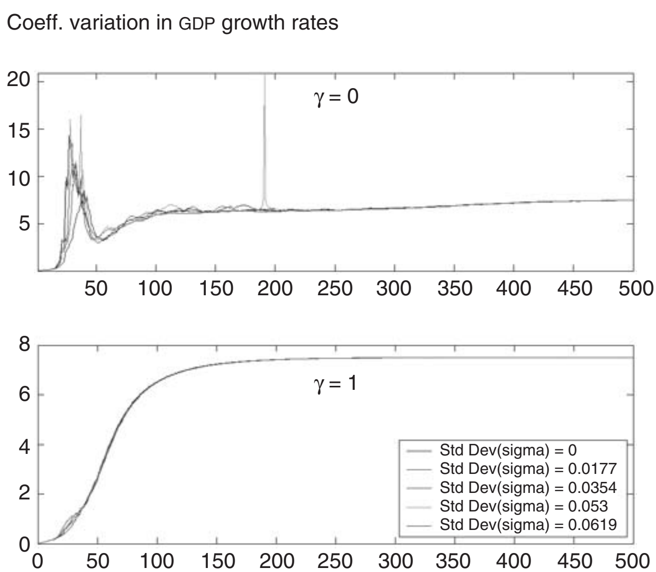


Figure 10. *Differences in GDP growth rates with heterogeneous $\bar{\sigma}_j$*

Figure 10 clearly shows that the effect of the technological heterogeneity on growth rates differences, when significant is concentrated in the first half of the simulations.

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

Figure 11. GDP *growth rates with heterogeneous* $\bar{\sigma}_j$

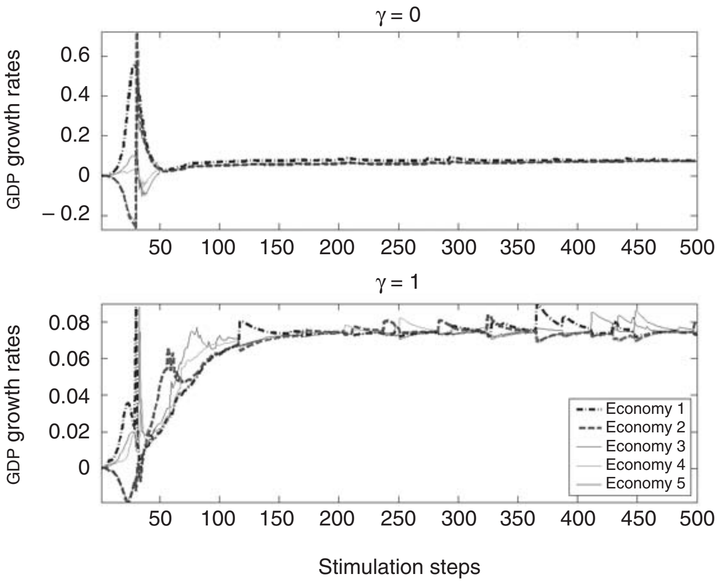


Figure 11 presents two example of simulation runs. These two examples illustrate two possible patterns generated by the introduction of heterogeneous technologies. When $\gamma = 1$, heterogeneous technological opportunities generates differences in productivity growth rates (see Figure 12), these generate differences in GDP growth rates (see the lower part in Figure 11), through changes in competitiveness; but these are absorbed through time by wages and by the increasing cost of R&D investments (*i.e.* wages). In this case transitory differences emerge but gradually fade and disappear.

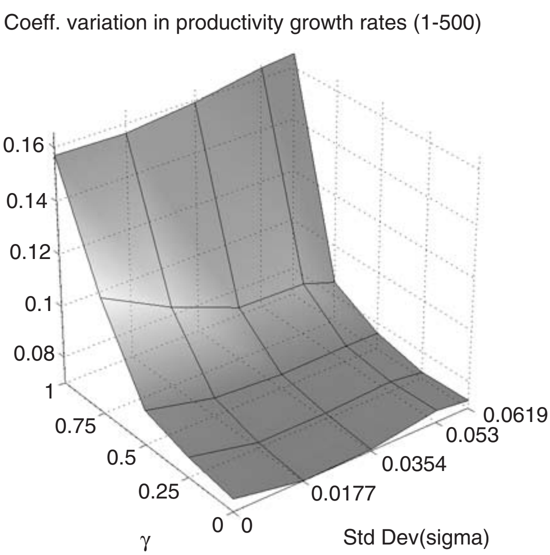


Figure 12. *Differences in productivity growth rates with heterogeneous* $\bar{\sigma}_j$ *and changes in* γ

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

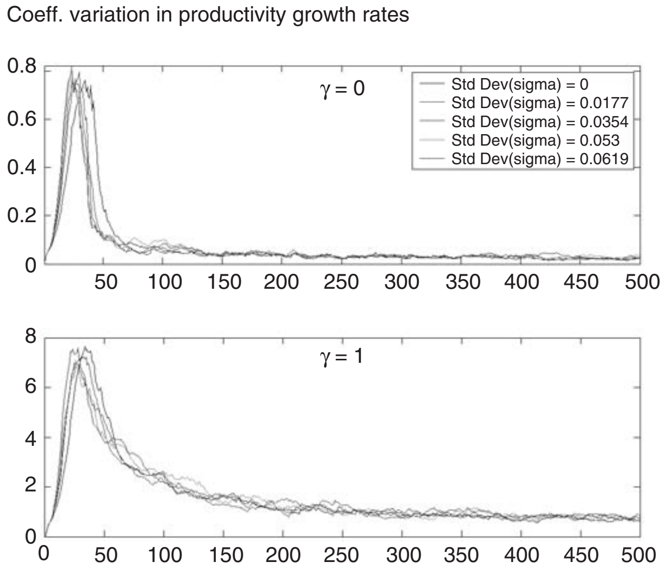


Figure 13. *Differences in productivity growth rates with heterogeneous* $\bar{\sigma}_j$

RESULT 5. *Heterogeneity in technological opportunities can generate vicious circles for specific settings of wages' adjustment mechanisms.*

When $\gamma = 0$, the differences in productivity growth rates (see Figure 13), 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 11), 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 6. *Increasing absorptive capacities has no significant effect on differences in GDP growth rates among economies.*

As depicted in Figure 14, increasing the access to technological spillovers seems to significantly reduce the differences in productivity growth rates 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.

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

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 1.

Figure 14. *Differences in GDP and productivity growth rates with changes in* χ

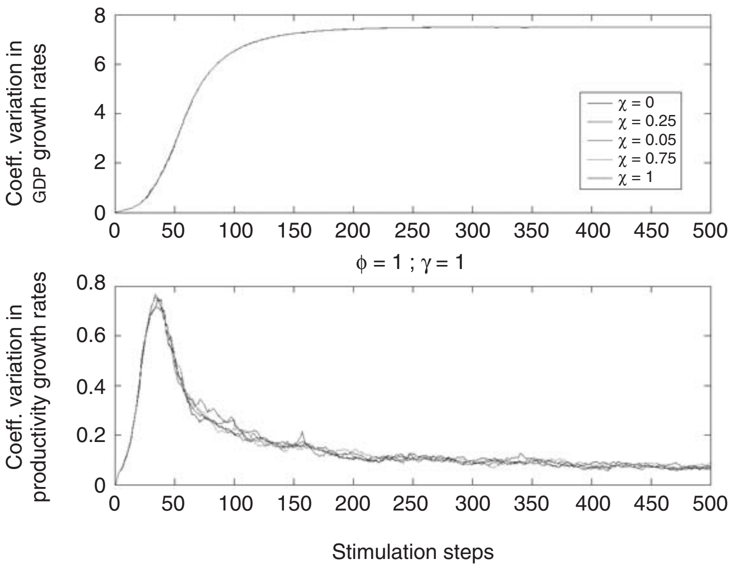


Table 1. *Main Simulation Results*

	↗ ϕ	↗ $StdDev(\alpha_j)$	↗ $StdDev(\bar{\sigma}_j)$	↗ χ
Low γ	↗ differences "*destructive divergence regime*"	↗ differences	↗ differences "*destructive divergence regime*"	no effect
High γ	↘ differences	↗ differences "*sustained differences regime*"	↗ differences "*transitory differences regime*"	no effect

CONCLUDING REMARKS

Our aim along this paper 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-founded technical change. We attempt here to open the "Kaldor-Verdoorn law blackbox", introducing these micro-foundations in traditional Kaldorian frame. We focus our analysis on the effect of six key parameters:

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

– 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 Lorentz (2004). Distinct regimes emerge, demand and technology driven. There again, the wage adjustment process allows the transmission of microshocks to macro-dynamics.

REFERENCES

AMABLE, B. (1992), "Effets d'apprentissage, compétitivité hors-prix et croissance cumulative", *Économie appliquée*.

AMENDOLA, M. and GAFFARD, J.-L. (1998), *Out of Equilibrium*, Oxford: Clarendon Press.

COMBIE, J.S.M. Mc and THIRLWALL, A.P. (1994), *Economic Growth and the Balance of Payments Constraint*, London: MacMillan Press.

DIXON, R. and THIRLWALL, A.P. (1975), "A Model of Regional Growth-rate Differences on Kaldorian Lines", *Oxford Economic Papers*.

DOSI, G., FABIANI, S., AVERSI, R. and MEACCI, M. (1994), "The Dynamics of International Differentiation: A Multi-country Evolutionary Model", *Industrial and Corporate Change*.

GAFFARD, J.-L. (1978), *Efficacité de l'investissement, croissance et fluctuation*, Paris: Cujas.

KALDOR, N. (1972), "The Irrelevance of Equilibrium Economics", *Economic Journal*.

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

KALDOR, N. (1981), "The Role of Increasing Returns, Technical Progress and Cumulative Causation in the Theory of International Trade and Economic Growth", *Économie appliquée*.

KALDOR, N. (1996), *Causes of Growth and Stagnation in the World Economy*, Cambridge: Cambridge University Press.

KWASNICKI, W. (2001), *Comparative Analysis of Selected Neo- Schumpeterian Models of industrial Dynamics*, Aalborg (Denmark): Nelson and Winter Conference.

LEÓN-LEDESMA, M.A. (2000), "Cumulative Growth and the Catching-Up Debate from a Disequilirium Standpoint", *Working Paper*, University of Kent, Canterbury.

LLERENA, P. and LORENTZ, A. (2004), "Co-evolution of Macro-dynamics and Technological Change: An Alternative View on Growth", *Revue d'économie industrielle* (Forthcoming).

LLERENA, P. and OLTRA, V. (2002), "Diversity of Innovative Strategy as a Source of Technological Performance", *Structural Change and Economic Dynamics*.

LORENTZ, A. (2004), "Sectoral Specialisation and Growth Rates Differences Among Integrated Economies", *Working Paper*, LEM, Sant'Anna School, Pisa.

METCALFE, J.S. (1998), *Evolutionary Economics and Creative Destruction*, London: Routledge.

NELSON, R.R. and WINTER, S. (1982), *An Evolutionary Theory of Economic Change*, Harvard University Press.

SILVERBERG, G. and VERSPAGEN, B. (1995), "Evolutionary Theorizing on Economic Growth", *Working paper*, MERIT, Maastricht.

VERSPAGEN, B. (1993), *Uneven Growth Between Interdependent Economies: Evolutionary Views on Technology Gaps, Trade and Growth*. Avenbury.

VERSPAGEN, B. (2002), "Evolutionary Macroeconomics: A Synthesis Between Neo-Schumpeterian and Post-Keynesian Lines of Thought", *The Electronic Journal of Evolutionary Modeling and Economic Dynamics*.

Revue économique — vol. 55, N° 6, novembre 2004, p. 1191-1214

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

ANNEX

SIMULATION SETTINGS

Table 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

Revue économique — vol. 55, N° 6, novembre 2004, p. 1191-1214

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po

Table 3. *Other parameters and initial conditions (set equally among economies and firms)*

	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
$\sigma_{i,j,c}$	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

Revue économique — vol. 55, N° 6, novembre 2004, p. 1191-1214

Document téléchargé depuis www.cairn.info - - - 130.79.212.183 - 29/01/2015 15h00. © Presses de Sciences Po