Is Agglomeration *really* good for Growth? Global Efficiency, Interregional Equity and Uneven Growth*

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Abstract

According to NEG literature (Baldwin *et al.* (2004)), spatial concentration of industrial activities increases growth at the regional and aggregate level without generating regional growth differentials. This view is not supported by the data. We extend the canonical model with an additional sector producing non-tradable goods which benefits from localized knowledge spillovers coming from the R&D performing industrial sector. This view, motivated by the evidence, generates both an anti-growth and a pro-growth effect of agglomeration for both the deindustrializing and the industrializing regions and leads to two novel results: 1) when agglomeration takes place, growth is lower in the periphery; 2) agglomeration may have a negative effect on the growth rate of real income, *both* at the regional *and* at the aggregate level. In particular, the economy as a whole might suffer a dynamic loss from agglomeration when: 1) the spatial range of the technological spillovers within the R&D sector; 2) the external benefit of local and foreign knowledge capital on non-tradable sector productivity; 3) the expenditure share on non-tradable goods are *all* large enough. These results are consistent with the empirical evidence reporting regional real income divergence and according to which the trade-off between aggregate growth and interregional equity loses relevance in more advanced stages of development. Our conclusions have relevant policy implications: contrary to the standard view, current EU and US regional policies favouring industrial dispersion might be welfare-improving both at the regional *and* the aggregate level and may reduce regional income disparities.

Key words: agglomeration; aggregate real growth; regional real growth; interregional equity; non-tradables; localized knowledge spillovers.

JEL Classifications: R10, O33, O41

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1 Introduction

An important aspect of new economic geography literature is the direct link between theoretical results and regional policy rules. One of the policy implications that can be drawn from some of these models (surveyed by Baldwin *et al.* (2004)) is particularly surprising at first sight: it is possible to increase the long-run aggregate economic growth and, at the same time, leave it uniform across regions by promoting policies aimed at favouring the agglomeration of the increasing-return sector activities in only one region. This conclusion is shared by many works belonging to a research programme - which we will dub as New Economic Geography and Growth (NEGG) - emerged in the late 1990s and inaugurated by Martin and Ottaviano (1999) who were the first to add endogenous growth features *à la* Romer (1990) to a version of the Krugman (1991) core-periphery model.

This rather optimistic view stems from the absence of any anti-growth effect of agglomeration for both the industrializing and the deindustrializing region. On the one hand, spatial concentration is good for aggregate growth because of localized intertemporal knowledge spillovers within the innovating sector[1]: when the spatial range of knowledge spillovers coming from the R&D activity performed by industrial firms is limited in space[2], then concentrating the industrial sector in only one region will minimize the cost of innovation and, then, maximize overall growth[3]. This implies that regional policies which favour industrial dispersion, for instance improving infrastructures in the poor region in order to attract firms, may not generate the equilibrium firms' allocation most favorable to aggregate growth. Hence, policy makers may be forced to choose between supporting lagging regions and promoting growth at the national level (Martin 1999).

On the other hand, although when agglomeration takes place knowledge capital stock grows at different rates in the two regions, regional real incomes *always* grow at the same rate so that real growth rate differential is nil whatever the degree of agglomeration. The reason is a "terms of trade effect". Thanks to the technological progress in the industrial sector, the price index of the manufacturing goods decreases faster than the price of the agricultural good. This implies that the relative value of the commodity which the periphery specializes in — traditional goods — increases overtime, making the periphery's imports of manufacturing goods cheaper. As a result, the real income of the periphery grows, in the long-run, at the same rate as the core[4].

These results do not depend on any assumption related to factor mobility: they are confirmed either when capital is assumed to be interregionally mobile (as in Martin and Ottaviano (1999), Martin (1999) and Dupont (2007)) or when it is assumed to be interregionally immobile (as in Baldwin *et al.* (2001), Bellone and Maupertuis (2003), Andrès (2007)) and either when labor is mobile between regions (as in Baldwin and Forslid (2000) and Fujita and Thisse (2003)) or when it is not (as in all the other cited papers). To sum up, the trade-off between aggregate growth and interregional equity and the absence of regional growth-gap appears to be very robust theoretical results.

Unfortunately, the empirical evidence does not support these predictions. Bruhlart and Sbergami (2009) investigate the impact of within-country spatial concentration of economic activity on country-

[1] For the sake of precision, localized spillovers are not the only way that geography can affect growth. Another way is to introduce vertical linkages through an intermediate input sector as in Martin and Ottaviano (2001) and Yamamoto (2002).

[2] Many empirical works support the local nature of knowledge flows. See, among the others, Keller (2002), Audretsch and Feldman (2004) and Peri (2005).

[3] With constant expenditure share on the industrial good, when intertemporal knowledge spillovers are global, growth is unaffected by the degree of concentration of the industrial sector and hence, geography does not matter for growth. However, these results are extended by Cerina and Mureddu (2008) who show that, when the elasticity of substitution between traditional and industrial goods is allowed to diverge from the unit value, agglomeration may have a pro-growth effect even when knowledge spillovers are global.

[4] As shown by Cerina and Pigliaru (2007), this rather optimistic result crucially depends on the Cobb-Douglas specification of the individual preferences between the two kinds of goods.

level growth. They find evidence that supports the so-called "Williamson hypothesis"(Williamson, 1965) according to which agglomeration boosts GDP growth only up to a certain level of economic development[5]. The authors then conclude that the trade-off between national growth and inter-regional equality may gradually lose its relevance as the world economy continues to grow. Henderson's (2003) analysis of the impact of urbanization on growth, is also supportive of the Williamson hypothesis: he finds that urbanization *per se* has no significant growth-promoting effect, but that urban primacy (the share of a country's largest city) is advantageous to growth in low-income countries. Two other works do not support the growth-promoting effect of spatial proximity: Henderson *et al.* (2001) report spatial deconcentration trends in fast-growing economies such as Korea, Brazil and Mexico, while Sbergami (2002) finds that, analyzing six European countries, dispersion of economic activities among regions favors growth at the national level.

As for regional growth differentials, the increasing regional disparities within European countries, which followed the spatial concentration trend during the 80s, is a widely accepted stylized fact (Puga, 2002). Moreover, in connection to the previous result, a relevant number of works (Cappellen *et al.* (2003), Gardiner *et al.* (2004), Giannetti (2002), Paci and Pigliaru (2002) among the others) show that western (and richest) EU regions exhibit divergence in real growth rates and this divergence reduces aggregate real growth rate in some countries (like Italy and France).

In this paper we show that NEGG theory might still be able to account for such evidence once non-tradable products are introduced in the analysis. As is well known, the largest share of GDP in middle and high income countries is, by far, represented by the production of non-tradable goods. In spite its importance in the world economy, NEGG literature has never dedicated particular attention to this category of products. Yet, non tradable goods and services have an exclusive characteristics which should be of interest for any theory of economic activity location: unlike most manufacturing and agricultural goods, they cannot be consumed (too) far away from the location where they are produced. This fact is rich of consequences if there is any kind of interdependency between the local non-tradable sector and the local manufacturing sector.

In our paper we explore this possibility by building a model which extends Baldwin *et al.* (2001) along the following lines: we add an additional sector producing non-tradable products (call it "services") whose productivity benefits from a positive externality coming from the local and, to a lesser extent, from the foreign stock of knowledge capital accumulated by the manufacturing sector. This externality might be justified in several ways but the most natural way to do it is to assume the existence of *localized intersectoral knowledge spillovers*. By generating an additional pro-growth effect and a novel anti-growth effect of agglomeration for both the deindustrializing *and* the industrializing region, the introduction of such sector leads to two novel results: 1) regional growth rates of real income are always different when agglomeration takes place, being lower in the periphery 2) agglomeration may have a negative effect on the growth rate of real income, *both* at the regional *and* at the aggregate level. The first result introduces the possibility of ever-increasing regional disparities and occurs because firms have no incentive to invest in knowledge in the deindustrializing region. As a consequence, because of localized intersectoral knowledge spillovers, peripheral consumers enjoy a slower decrease in the price of the non-tradable goods since, by definition, their regional price dynamics follow different rules. The second result means that agglomeration might be bad for growth for the periphery, the core and at the aggregate level. In particular, the economy as a whole might suffer a dynamic loss from agglomeration, meaning that aggregate growth and interregional equity do not necessarily conflict. That happens when: 1) the spatial range of the intrasectoral spillovers within the R&D sector 2) the strength of the external benefit

[5]Roughly the current per-capita income level of Brasil and Bulgaria, one of the poorest country of the EU.

of local and foreign knowledge capital on non-tradable sector productivity 3) the expenditure share of non-tradable goods are *all* large enough. When this is the case, the loss of productivity suffered by the deindustrialized region (and possibly but less likely by the industrialized region) is not compensated, at the aggregate level, by the reduced cost of innovation due to higher spatial concentration of knowledge capital. Therefore, aggregate real growth is lower when industrial agglomeration takes place.

If we consider that the stylized facts on structural change (Kutsnets 1973, Kongsamut *et al.*, 2001, Buera and Kaboski 2009) and on the technology of knowledge diffusion (Baldwin *et al.*, 2001, Keller 2002) suggest that all these parameters increase as the economy reaches more advanced stages of development, then our model offers a natural mechanism to reduce the gap between theory and data, particularly in advanced countries.

From the policy perspective, an interesting application of our model is given by the current European Regional Policies. As clearly stated in official documents of the EU Commission, the explicit goal of EU regional policy appears to be not simply to redistribute income between rich and poor regions, but to attract production to peripheral locations[6]. This goal is all the more confirmed by the fact that a substantial share of the budget of EU regional policies (which by themselves amount to one third of the total EU budget), consists of direct or indirect subsidies to private firms located in poor regions (Dupont and Martin 2006) [7]. We believe that our results might have important consequences for policy makers: if we accept that the presence of a non-tradable sector which benefits from the local innovating sector (i.e.: innovating and financial services, health, education, military services, technical support, IT services, retail, communications, real estate and housing) is a realistic feature of the economy, then policies that favor agglomeration may generate ever-increasing regional inequalities and may be detrimental to overall growth. In our paper we formalize the conditions under which pro-dispersion policies are good for aggregate real growth. In other words, while other NEGG works (among others, Martin 1999) raise relevant doubts regarding the efficiency of EU regional policies, we provide a theoretical framework where EU policies might be justified on the basis of both equity and efficiency arguments. In doing that, we also provide a candidate explanation for the recent empirical findings by Busillo *et al.* (2010) who demonstrate, using a regression discontinuity design approach, that Cohesion policies have had a positive growth effect on EU poorest regions.

The paper will proceed as follows: in section 2 we present the analytical framework and we provide empirical support for our key assumptions. Section 3 is dedicated to the agglomeration mechanism and to the stability analysis of locational equilibria. Section 4 develops the analysis of regional and aggregate real growth while section 5 analyses in detail the trade-off between global efficiency and interregional equity. Finally, section 6 concludes and draws some policy implications.

[6]Consider, for instance, the Second Cohesion Report: "The Treaty [of the European Community], by making explicit the aim of reducing disparities in economic development, implicitly requires that EU policies, and cohesion measures in particular, should influence factor endowment and resource allocation and, in turn, promote economic growth. More specifically, cohesion policies are aimed at increasing investment to achieve higher growth and are not specifically concerned either with expanding consumption directly or with redistribution of income" (EU Commission (2001), p. 117).

[7]It is worth adding that the objective to attract economic activities in poor regions is not only an EU prerogative, but it is shared either by European national governments (think about "State Aid" and the Italian Mezzogiorno policies) and even by the US Federal Government which, despite the lower degree of interregional disparities, spends roughly $20–30 billion in state and local government spending devoted to subsidies to private firms located in disadvantaged areas, mostly in the form of tax breaks, with perhaps another $6 billion annually in support from the federal government (Bartik, 2002).

2 The Analytical Framework

2.1 The Structure of the Economy

Our economy is modeled along the lines of Baldwin *et al.* (2001). The crucial departure from the latter is the additional sector producing non-tradable goods which we define as *services.*

We assume two symmetric regions in terms of technology, preferences, transport costs and initial endowments. Each region is endowed with two production factors: labor L and capital K. Four production sectors are active in each region: modern (manufacture) M, traditional (agriculture) T, a capital producing sector I and a service producing sector S. Labor is assumed to be immobile across regions but mobile across sectors within the same region. The traditional good is freely traded between regions whilst manufactures are subject to iceberg trade costs[8]. For the sake of simplicity, we will mainly focus on the Northern region[9].

The manufactures are produced under Dixit-Stiglitz monopolistic competition (Dixit and Stiglitz, 1977) and enjoy increasing returns to scale: firms face a fixed cost in terms of knowledge capital. It is in fact assumed that producing a variety requires a unit of knowledge interpreted as a blueprint, an idea, a new technology, a patent, a machinery or even a particular enterpreneural skill. Moreover firms face a variable cost a_M in terms of labor. Thereby the cost function is $\pi + w_M a_M x_i$, where π is the rental rate of capital, w_M is the wage rate in the $M-$sector and a_M are the unit of labor necessary to produce a unit of output x_i.

Each region's K is produced by its I-sector which produces one unit of K with a_I units of labor. So the production and marginal cost function for the I-sector are, respectively:

$$\dot{K} = Q_K = \frac{L_I}{a_I} \quad (1)$$

$$F = w_I a_I \quad (2)$$

Note that this unit of capital in equilibrium is also the fixed cost F of the manufacturing sector. As one unit of capital is required to start a new variety, the number of varieties and of firms at the world level is simply equal to the capital stock at the world level: $K + K^* = K^w$. We denote n and n^* the number of firms located in the North and South respectively. As one unit of capital per firm is required we also know that: $n + n^* = n^w = K^w$. However, depending on the assumptions we make on capital mobility, the stock of capital produced and owned by one region may or may not be equal to the number of firms producing in that region. In the case of capital mobility (as in Martin and Ottaviano, 1999), the capital may be produced in one region but the firm that uses this capital unit may be operating in another region. Hence, when capital is mobile, the number of firms located in one region is generally different from the stock of capital owned by this region. In this case, K is better interpreted as physical capital (mobility then means delocation of plants) or codified knowledge capital tradable through patents. By contrast when capital is immobile, as in Baldwin *et al.* (2001), each firm operates - and its owner spends his profits - in the region where the capital unit has been created. If this is the case, we have that $n = K$ and $n^* = K^*$. Then, by defining $s_n = \frac{n}{n^w}$ and $s_K = \frac{K}{K^w}$, we also have $s_n = s_K$: the share of firms located in one region is equal to the share of capital owned by the same region. This second case, capital immobility, would be more consistent with the interpretation of K as tacit embodied knowledge capital or human capital. In this case, labor immobility implies capital immobility. Following Baldwin *et al.* (2001), we will concentrate on the case of capital immobility[10]. In this case, K represents both the

[8] It is assumed that a portion of the good traded melts in transit.

[9] Unless differently stated, the Southern expressions are isomorphic.

[10] It can be shown however that our main results can be easily extended to the case of capital mobility.

number of Northern manufacturing firms *and* the Northern cumulative output of the innovating sector. This equivalence will be important in order to interpret the intersectoral spillovers assumption.

To individual I-firms, the innovation cost a_I is a parameter. However, following Romer (1990), endogenous and sustained growth is provided by assuming that the marginal cost of producing new capital declines (i.e., a_I falls) as the sector's cumulative output rises. In our specification, learning spillovers are assumed to be local. The cost of innovation can be expressed as:

$$a_I = \frac{1}{AK^w} \tag{3}$$

where $A \equiv s_K + \lambda(1 - s_K)$, $0 < \lambda < 1$ measures the degree of globalization of learning spillovers and $s_K = K/K^w$ is the share of firms located in the North. The South's cost function is isomorphic, that is, $F^* = w_I^*/K^w A^*$ where $A^* = \lambda s_K + 1 - s_K$. For the sake of simplicity in the model version we examine, capital depreciation is ignored[11].

Because the number of firms, varieties and capital units is equal, the growth rate of the number of varieties, on which we focus, is therefore:

$$g \equiv \frac{\dot{K}}{K}; g^* \equiv \frac{\dot{K}^*}{K^*} \tag{4}$$

Finally, the T-sector produces a homogeneous good in perfect competition and constant returns to scale. By choice of units, one unit of T is made with one unit of L.

2.2 The Non-tradable Sector

The introduction of a sector producing non-tradable goods which benefits from the proximity of the stock of knowledge capital created for the manufacturing sector represents the crucial point of this paper. All the results related to regional growth patterns are driven by the interaction of this sector, the S-sector, with the rest of the economy. Before providing a formal representation of this sector, it is worth discussing its characteristics and their empirical content.

2.2.1 Non-tradability

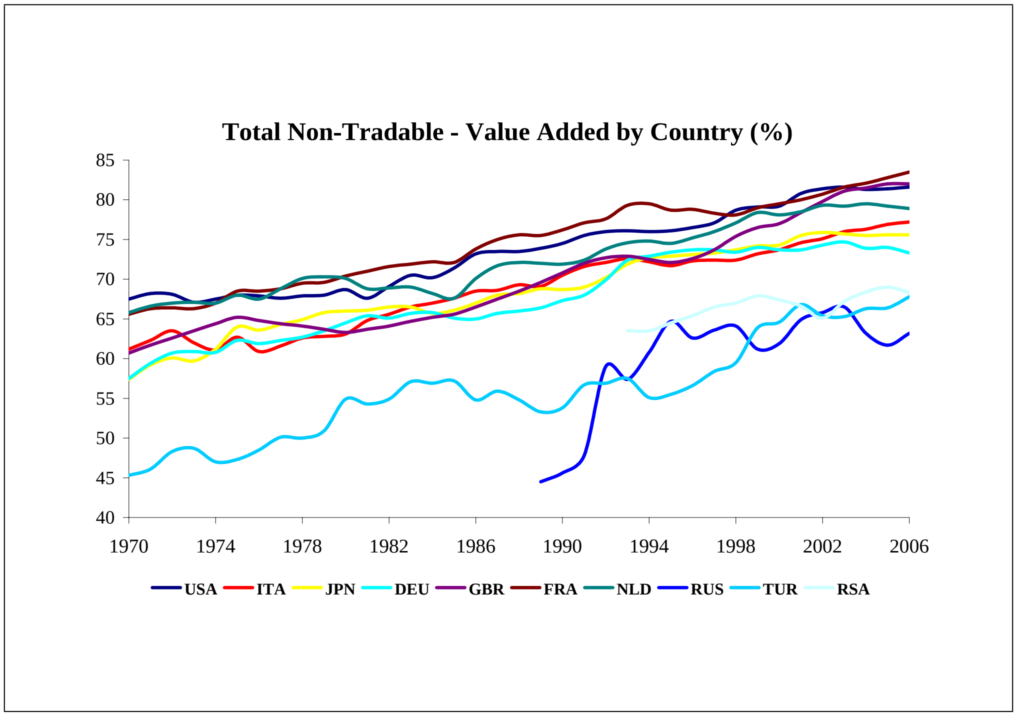
As is well known, the largest share of GDP in middle and high income countries is, by far, represented by the production of non-tradable goods. Figure 1 shows that the share of non-tradable goods (identified, following the literature, by services and construction) reaches about 70 percent in middle income countries like Turkey, Brazil, Russia and Mexico and often surpasses 80 percent in high-income countries like USA, UK, Italy, France, Germany and so on. Moreover, and consistently with the literature on structural change (Buera and Keboski 2009, Kongsamut *et al.* 2001 among many others), this share has tremendously increased over the past 40-50 years and it is still increasing especially in middle income countries.

One might observe, as Blinder (2005) that the enormous progress in the information communication technology has led to a situation in which a relevant share of services (essentially business related services like IT services and consultancy) can be - and will be more and more in the future - interregionally and internationally traded[12]. However, as table 1 shows, although the share of internationally traded services

[11] See Baldwin (2000) and Baldwin *et al.* (2004) for similar analysis with depreciation

[12] According to Blinder (2005): "'Of course, not everything can be traded across national borders. At any point in time, the available technology-especially transportation and communications technologies-largely determines which goods and services are easy to trade internationally and which are hard or impossible to trade. (...) Traditionally, any item that can be put in a box and shipped (roughly, manufactured goods) was considered tradable, while anything that cannot be put in a box (like services) or was too heavy for shipping (like houses) was thought of as non-tradable. (...). Because technology is constantly improving, and because transportation seems to grow easier and cheaper over time, the boundary between what is tradable and what is not tradable is constantly shifting (...): Over time, more and more items become tradable.(...)

Figure 1: The relevance of non-tradables increases over time (Source: OECD STAN)



over GDP has increased from 1990 to 2005 at about the same rate as manufacturing goods, such share is still about seven times smaller that the latter (10 vs. 60 per cent as world average). International trade in services is even smaller, relative to manufactures, when we measure it as the share of each sector's GDP which in the case of services, is more than 3 times the sectoral GDP of manufacturing in most countries.

For all those reasons, considering the service sector as a basically non-tradable sector still appears to be a good approximation of reality and the fact that other growing sectors like housing and real estate are intrinsically non-tradable suggests that the existence of a massive category of non-tradable goods is still - and will remain - a realistic and significant feature of real economies, particularly if referring to consumer services, which is the target of our analysis.

Despite its importance in the world economy, and quite surprisingly, NEG literature has never dedicated particular attention to this category of products[13], especially when growth issues are taken into account. Yet, non tradable goods and services have an exclusive characteristics which should be of interest for any theory of economic activity location: unlike most manufacturing and agricultural goods, they cannot be consumed (too) far away from the location where they are produced. I cannot undertake surgery being distant from where the surgeon is located; I cannot enjoy hotels and restaurants, leisure and recreational facilities, parks, clean air, good institutional quality, well-organized wholesale retail, social, elderly and child care, social security, car repair, hairdressers and cosmeticians, military defence, public transport and energy and telecommunications network, being far from where the production of such goods is located. I can buy some on-line education but, by large majority, education has to be

Because packets of digitized information can now play the role that boxes used to play, many services are now tradable and many more will surely become so."' (Blinder 2005, p.4-5)

[13] Two exceptions are Behrens (2004) and Tabuchi and Thisse (2002).

Table 1: Trade in services is relatively limited (Source: WDI 2007)

	Merchandise(GDP %)		**Services(GDP %)**	
	1990	**2005**	**1990**	**2005**
Low Income	23.6	41.1	6.2	9.8
Middle Income	34.5	62.1	7.1	10.5
Lower Middle Income	31.6	58.9	6.4	10
Upper Middle Income	38.3	66.4	8	11.1
Low & Middle Income	32.5	59.2	7	10.6
East Asia & Pacific	47.1	74.6	7.3	10.3
Europe & Central Asia	49.7	68.6	7.1	12.6
Latin America & Carib.	23.2	44.2	5.7	6.8
Middle East and N. Africa	43.5	57.6	9.2	
South Asia	16.5	31.2	4.2	8.2
Sub-Saharan Africa	41.9	57.8	10.8	13.1
High Income	32.3	43.9	7.9	11.1
Europe EMU	44	61.4	11	15.9

undertaken where teachers are located. To some extent I can enjoy on-line banking and financial services but still face-to-face interaction and physical (and cultural) proximity between borrowers and lenders appear to be fundamental.

In other words, by definition, local consumption of non-tradable goods implies local production of them and vice-versa. As an implication, since regionally produced S-goods cannot be part of the same integrated market and regional price dynamics are completely independent, any loss in the productivity of local non-tradable sector will negatively affect the utility of local individuals only and it will also negatively affect the aggregate performance of the whole economy. This fact is rich of consequences if there is any kind of interdependency between the local non-tradable sector and the local manufacturing sector. In what follows we discuss and explore this possibility.

2.2.2 Localized Intersectoral knowledge spillovers

The second crucial characteristic of our S-sector is that its productivity benefits from a positive externality coming from the local and, to a lesser extent, from the foreign stock of knowledge capital. Since, as already noted, the regional stock of knowledge capital coincides with the number of regional manufacturing firms, it is a matter of definition whether such external effect on services productivity comes from the cumulative output of the innovating sector or from the size of the manufacturing sector. In the rest of the paper these two definitions will be interchangeable.

Whatever its nature, if this kind of localized interdependency between the non-tradable sector and the manufacturing sector exists, then our model predicts a quite different growth prospect with respect to standard NEGG models.

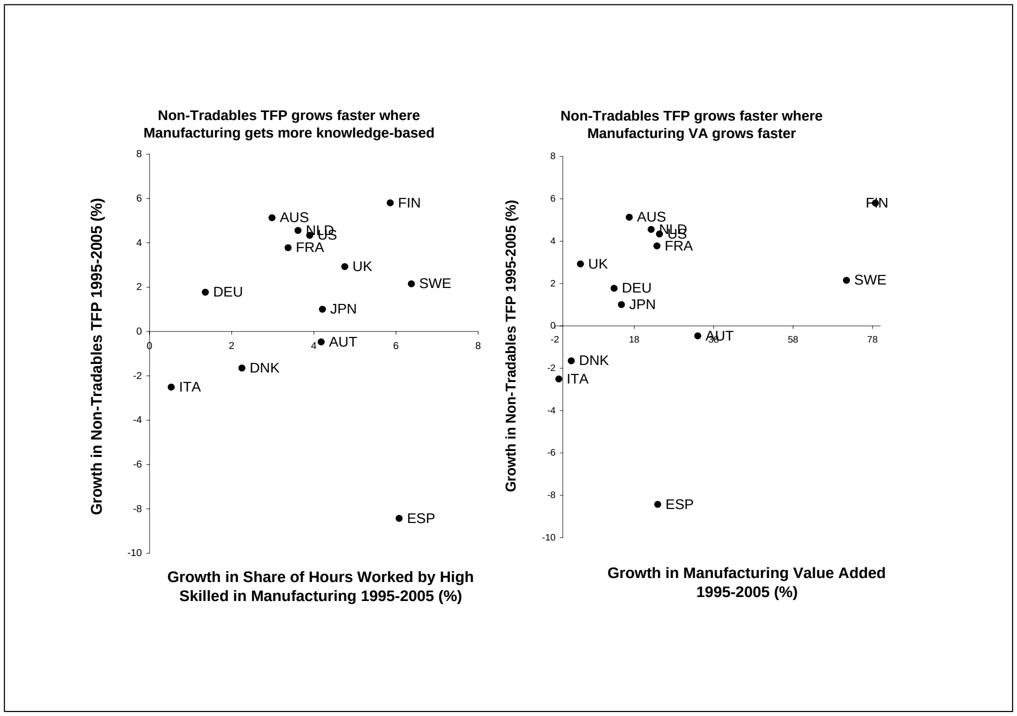
Even if it is not our aim to provide a microfoundation analysis of such external effect (we leave this topic to future research), we believe that the most natural way to justify it is to consider it as a form of *localized knowledge intersectoral spillover*. There are several arguments which provide empirical support to this assumption.

First of all, a natural extension of the massive literature on localized knowledge flows suggests that technology-intensive non-tradable goods like constructions, health, military, banking and financial services, telecommunications and energy networks, etc. may well take advantage of the proximity of knowledge capital created for the manufacturing sector. Moreover, since these productivity gains may not be driven only by exclusively *technological* knowledge flows but also by better organizational efficiency, the kind of intersectoral knowledge spillovers we have in mind might also involve less technologically intense service sectors like wholesale retail, leisure and entertainment, education, social care, hairdressers and cosmetician, public administration and so on. In other words, our claim is that the local proximity of a thriving knowledge-producing activity connected to the industrial sector might be helpful to induce the local non-tradable sector to implement technological and organizational innovation which eventually have a positive effect on individuals' welfare.

Secondly, there are many empirical works which support the existence of such knowledge spillovers. A first support of this view can be traced back to Glaeser *et al.* (1992) in their analysis of the relationship between localized knowledge spillovers and the growth of the cities. By analyzing a data set on geographic concentration and competition of manufacturing and service firms in 170 of the largest US cities, they find that important knowledge spillovers might occur *between* (the so-called Jacobs spillovers) than *within* industries (the so-called Marshall-Arrow-Romer spillovers). In other words, Glaeser *et al.* (1992) find that the externality associated by Jacobian knowledge spillovers based on diversity, are substantially more intense than the externality associated to MAR knowledge spillovers based on specialization. Therefore, by adding an interindustry localized knowledge spillover to the standard intraindustry spillover within the innovating sector, our model seems to go towards the direction indicated by Glaeser *et al.* (1992). Our view is also supported by van Meijl (1997) and Potì and Cerulli (2007) who find significant knowledge spillovers from R&D activity on services like financial intermediation, computer services, transport, storage and communication. Park (2004) as well offers evidence that manufacturing R&D has a substantial intersectoral R&D spillover effect on domestic non-manufacturing productivity growth while Park and Chan (1989) suggest that the intersectoral relationships between manufacturing and services generally characterize asymmetrical dependence, namely, service activities tend to depend on the manufacturing sector as a source of inputs to a far greater extent than vice versa. A similar finding is reported by Kaiser (2002) in his analysis of the diffusion of knowledge in a large dataset of German manufacturing and services firms (wholesale and retail trade, transport, traffic, banking, insurance, software, technical consultancy, marketing, and 'other' business related services): he finds that the probability that a service firm uses customers from the manufacturing sector as a source for innovation is much higher than the probability that a manufacturing firm uses customers from the service sector as a source of innovation. Finally, Quella (2006) reported evidence according to which, among six large macroeconomic sectors (Manufacturing, Mining, Construction, Services, Trade & Transportation, Agriculture) covering the totality of US civilian economy from 1948 to 1991: 1) most knowledge flows occur between industry and the tertiary sector; 2) these knowledge flows are largely unidirectional because manufacturing is the main source of spillovers in the economy while services (and agriculture), on the other hand, do not contribute at all to the generation of knowledge, neither internally nor externally. These findings are perfectly compatible with the way we model the interdependency between our M-sector and and S-sector.

Third, to further reinforce our argument, we provide some supportive evidence of localized intersectoral spillovers between industry and services. From the EU Klems (2007) dataset we have considered the growth rate of service Total Factor Productivity for all the 11 available countries (UK, Italy, Spain, Austria, Japan, Denmark, US, The Netherlands, France, Australia, Germany) and we have plotted it with 1) the growth rate of hours worked by skilled workers in the manufacturing sector - as a proxy for the stock of (embodied) knowledge capital, figure 2 (left) - and 2) the growth rate of the value added of the manufacturing sector - as a proxy for its size, figure 2 (right). In both cases the correlation is clearly positive (with Spain as an outlier) meaning that, over a period of 15 years, the sectoral TFP in services grew faster in countries where both skilled work in manufactures and valued added in the manufacturing sector grew faster. Although these empirical findings are far from being taken as causal relationships, they certainly do not contradict our assumption of intersectoral knowledge spillovers from manufacturing to the service sector.

Figure 2: Correlation between non-tradables TFP and manufacture (Source: own computations based on EU KLEMS 2007)



Taking into account all these considerations, we now turn to the analytics of the S-sector.

2.2.3 A formal representation of the S-sector

As far as our aims are concerned, our non-tradable sector might be formally represented in a very simple and stylized way. Our S-sector works in perfect competition and constant returns to scale, with $a_S(\cdot)$ units of labor necessary to produce one unit of output. Its production function is very similar to that of the innovation and traditional sector:

$$S = \frac{L_S}{a_S(\cdot)}; S^* = \frac{L_S^*}{a_S^*(\cdot)} \tag{5}$$

where S is the quantity of services produced in the North and L_S is the labor force devoted to the production of services. Moreover $a_S(\cdot)$ represents the labor units requirements per unit of production and $S-$firms take it as given. The latter is a crucial variable in our model as it represents an inverse measure of labor productivity in the non-tradable sector. Firms' optimization implies the following pricing rule:

$$p_S = w_S a_S(\cdot) \tag{6}$$

$$p_S^* = w_S^* a_S^*(\cdot) \tag{7}$$

where the price level depends upon the wage rate and the labor units requirements.

The intersectoral spillovers between R&D and services are specified in the following way:

$$a_S(\cdot) = a_S(K, K^*) \tag{8}$$
$$a_S^*(\cdot) = a_S^*(K, K^*) \tag{9}$$

with:

$$\frac{\partial a_S(K,K^*)}{\partial K}, \frac{\partial a_S(K,K^*)}{\partial K^*}, \frac{\partial a_S^*(K,K^*)}{\partial K}, \frac{\partial a_S^*(K,K^*)}{\partial K^*} < 0 \tag{10}$$

so that the production cost of non-tradables is negatively affected by an increase in the stock of knowledge capital located in any of the two regions (K or K^*). However, as already said, intersectoral knowledge spillovers are *localized* in the sense that the cost reduction is not smaller, and generally larger, when knowledge is spilled from the stock of knowledge located in the same region[14]:

$$|\theta_K(K,K^*)| \geq |\theta_{K^*}(K,K^*)|, \forall (K,K^*) \tag{11}$$

and:

$$|\theta_{K^*}^*(K,K^*)| \geq |\theta_K^*(K,K^*)|, \forall (K,K^*) \tag{12}$$

where

$$\begin{bmatrix} \frac{\partial a_S(K,K^*)}{\partial K}\frac{K}{a_s(K,K^*)} & \frac{\partial a_S(K,K^*)}{\partial K^*}\frac{K^*}{a_s(K,K^*)} \\ \frac{\partial a_S^*(K,K^*)}{\partial K}\frac{K}{a_s^*(K,K^*)} & \frac{\partial a_S^*(K,K^*)}{\partial K^*}\frac{K^*}{a_s^*(K,K^*)} \end{bmatrix} \equiv \begin{bmatrix} \theta_K(K,K^*) & \theta_{K^*}(K,K^*) \\ \theta_K^*(K,K^*) & \theta_{K^*}^*(K,K^*) \end{bmatrix} \tag{13}$$

is the matrix of the elasticities of labor units requirements of the $S-$sector with respect to both local and foreign knowledge capital (*spillover matrix* from now on). It is important to highlight that the case of *global* intersectoral knowledge spillovers is therefore just a particular case of localized spillover, i.e., when (8) and (9) hold with equality. As we will see, regional and aggregate growth patterns differ widely according to whether intersectoral knowledge spillovers are global or local.

Since regions are symmetric in terms of technology, we have:

$$\begin{cases} \theta_K(K,K^*) = \theta_{K^*}^*(K,K^*) < 0 \\ \theta_{K^*}(K,K^*) = \theta_K^*(K,K^*) < 0 \end{cases} \forall (K,K^*) \tag{14}$$

that is, the spillover matrix expressed in (13) is symmetric.

Two observations are worthy at this point. First, we remind that all these four elasticities take negative values. Second, and most importantly, at this stage we do not need to specify an explicit functional form for the cost parameters $a_S(K,K^*)$ and $a_S^*(K,K^*)$. However, it is important to highlight that, in order for the growth rate of *real* income to be constant in both regions, the cost parameters functional form should be such that all the related elasticities are constant, that is:

$$\forall (K,K^*), \begin{cases} \theta_K(K,K^*) = \theta_K \\ \theta_{K^*}(K,K^*) = \theta_{K^*} \\ \theta_{K^*}^*(K,K^*) = \theta_{K^*}^* \\ \theta_K^*(K,K^*) = \theta_K^* \end{cases} \tag{15}$$

[14] An important implication of this assumption is that the price of services decreases faster, and becomes permanently lower, in the industrialized region. This assumption may look against the evidence according to which (Bhagwati, 1984 among the others) services are cheaper in less industrialized countries. Even so, the main reason why it happens is that the quality of services in the industrialized countries is higher. We can then bypass this problem by simply considering p_s as the price of service *per unit of quality*.

2.3 Preferences and Consumers' Behaviour

As in the standard NEGG models, the infinitely-live representative consumer's optimization is carried out in three stages. In the first stage the agent intertemporally allocates consumption between expenditure and savings. In the second stage she allocates expenditure between manufacturing goods, traditional goods and services, while in the last stage she allocates manufacture expenditure across varieties. The preferences structure of the infinitely-live representative agent is then given by:

$$\begin{aligned} U_t &= \int_{t=0}^{\infty} e^{-\rho t} \ln Q_t dt && (16) \\ Q_t &= C_M^{\alpha} C_T^{\beta} C_S^{\gamma} && (17) \\ C_M &= \left[\int_{i=0}^{K+K^*} c_i^{1-1/\sigma} di \right]^{\frac{1}{1-1/\sigma}} && (18) \\ \alpha + \beta + \gamma &= 1 \end{aligned}$$

Where C_M, C_T and C_S are respectively the preference index aggregator for the manufacturing varieties, the consumption level of the traditional good and the consumption level of services. As a result of the intertemporal optimization program, the path of consumption expenditure E across time is given by the standard Euler equation:

$$\frac{\dot{E}}{E} = r - \rho \tag{19}$$

with the interest rate r satisfying the no-arbitrage-opportunity condition between investment in the safe asset and capital accumulation:

$$r = \frac{\pi}{F} + \frac{\dot{F}}{F} \tag{20}$$

where π is the rental rate of capital and F its asset value which, due to perfect competition in the I-sector, is equal to its marginal cost of production.

In the second stage of the utility maximization the agent chooses how to allocate the expenditure between M-, S- and the T-good according to the following optimization program:

$$\begin{aligned} \max_{C_M, C_T, C_S} Q_t &= \ln \left(C_M^{\alpha} C_T^{\beta} C_S^{\gamma} \right) && (21) \\ s.t.\ E &= P_M C_M + p_T C_T + p_S C_S \end{aligned}$$

Yielding the following demand functions:

$$C_M = \alpha \frac{E}{P_M} \tag{22}$$

$$C_T = \beta \frac{E}{p_T} \tag{23}$$

$$C_S = \gamma \frac{E}{p_S} \tag{24}$$

where p_T is the price of the Traditional good, p_S is the price of the non-tradable good, and $P_M = \left[\int_{i=0}^{K+K^*} {p_i}^{1-\sigma} di \right]^{\frac{1}{1-\sigma}}$ is the Dixit-Stiglitz price index for the manufacturing differentiated good.

Finally, in the third stage, the amount of $M-$ goods expenditure αE is allocated across varieties according to the a CES demand function for a typical M variety $c_j = \frac{p_j^{-\sigma}}{P_M^{1-\sigma}} \alpha E$, where p_j is variety j's consumer price.

2.4 Wages and Prices

Due to perfect competition in the T-sector, the price of the agricultural good must be equal to the wage of the T-sector's workers: $p_T = w_T$. Moreover, *as long as both regions produce some* T, the assumption of free trade in T implies that not only price, but also wages are equalized across regions. It is therefore convenient to choose home labor as numeraire so that:

$$p_T = p_T^* = w_T = w_T^* = 1 \tag{25}$$

It's not always the case that both regions produce some T. In order to avoid complete specialization we need to assume that a single country's labor endowment must be insufficient to meet global demand. Formally:

$$L = L^* < \beta E^w \tag{26}$$

where $E^w = E + E^*$.

The purpose of making this assumption, which is standard in most NEGG models[15], is to maintain wages fixed at the unit value: since labor is mobile across sectors, as long as the T-sector is present in both regions, a simple arbitrage condition would suggest that wages of the three sectors cannot differ. Hence, $M-$ and $S-$sector wages are tied to T-sector wages which, in turn, remain fixed at the level of the unit price of the T-good. Therefore:

$$w_M = w_M^* = w_T = w_T^* = w_S = w_S^* = w = 1 \tag{27}$$

Finally, since wages are uniform and all varieties' demands have the same constant elasticity σ, firms' profit maximization yields local and export prices that are identical for all varieties no matter where they are produced: $p = w a_M \frac{\sigma}{\sigma-1}$. Then, by imposing the normalization $a_M = \frac{\sigma-1}{\sigma}$ and equation (27), we finally have:

$$p = w = 1 \tag{28}$$

As usual, since trade in M is impeded by iceberg import barriers, prices for markets abroad are higher:

$$p^* = \tau p;\ \tau \geq 1 \tag{29}$$

By labeling as p_M^{ij} the price of a particular variety produced in region i and sold in region j (so that $p^{ij} = \tau p^{ii}$) and by imposing $p = 1$, the $M-$goods price indexes might be expressed as follows:

$$P_M = \left[\int_0^K (p_M^{NN})^{1-\sigma} di + \int_0^{K^*} (p_M^{SN})^{1-\sigma} di\right]^{\frac{1}{1-\sigma}} = \left(s_K + (1-s_K)\,\phi\right)^{\frac{1}{1-\sigma}} K^{w\,\frac{1}{1-\sigma}} \tag{30}$$

$$P_M^* = \left[\int_0^K (p_M^{NS})^{1-\sigma} di + \int_0^{K^*} (p_M^{SS})^{1-\sigma} di\right]^{\frac{1}{1-\sigma}} = \left(\phi s_K + 1 - s_K\right)^{\frac{1}{1-\sigma}} K^{w\,\frac{1}{1-\sigma}} \tag{31}$$

where $\phi = \tau^{1-\sigma}$ is the so called "phi-ness of trade" which ranges from 0 (prohibitive trade) to 1 (costless trade).

[15]See Bellone and Maupertuis (2003) and Andrès (2007) for the analytical implications of removing this assumption

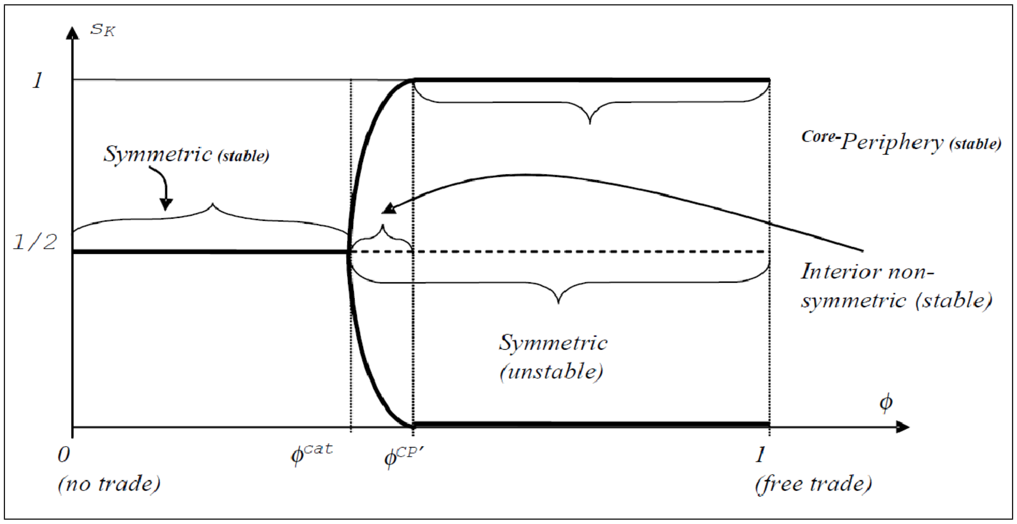


Figure 3: The map of locational equilibria (from Baldwin *et al.* (2001))

3 Stability of Locational Equilibria

Agglomeration patterns in our model are identical to Baldwin *et al.* (2001). In other words, the presence of a non-tradable sector (the way we modeled it) does not affect the standard mechanisms of industry agglomeration. This is because the interaction between the S- and the M-sector is assumed to be unidirectional: services productivity is positively affected by manufactures but *not* vice-versa[16]. Hence, the equilibrium spatial distribution of manufacturing firms and its stability are totally independent from what happens in the S-sector.

For the same reason, as shown in the appendix, the dynamic system describing the evolution of the economy overtime is the same as the one illustrated in Baldwin *et al.* (2001). As in the latter, the stability of the location equilibria in our model is determined by the interaction between two destabilizing forces - the market access effect and the localized spillovers effect - and one stabilizing force, the market crowding effect. The market access effect is due to the fact that the more agglomerated region is more attractive because manufacturing firms enjoy increasing returns to scale and therefore are attracted by larger markets, while the localized spillovers effect is determined by the fact that innovation activity is more productive in the region owning a higher capital share. By contrast the dispersion force called market crowding effect is given by the fact that competition is tougher in the more industrialized region.

When transport costs are high, the market crowding effect is stronger than the market access and the localized spillovers effects. On the contrary when trade costs begin to fall, the strength of the market crowding effect weakens faster than the market access effect and the localized spillovers effects (which are not affected by trade costs) thereby leading to (catastrophic) agglomeration.

The map of locational equilibria is then described by figure 3, taken from Baldwin *et al.* (2001)

As the figure shows, when ϕ is sufficiently high and trade is not as easy ($\phi \leq \phi^{cat}$), the only stable equilibrium is the symmetric one, where $s_K = 1/2$. When trade costs fall and ϕ becomes larger than ϕ^{cat}, two additional steady states appear. In other words, when ϕ rises from below to above ϕ^{cat}, the symmetric steady state loses its stability to the two new neighboring interior steady states. As ϕ becomes

[16] As already said, an empirical support of this assumption can be found in Park and Chan (1989), Kaiser (2002) and Quella (2006). However, an interesting future line of research might be the analysis of the implications of a reciprocal influence of the manufacturing and service sector with the productivity of $M-$ firms either being positively affected by the presence of firms producing non-tradable services or using non-tradable services as an intermediate input.

larger, these two interior steady states approach the two core-periphery equilibria ($s_K = 0$ and $s_K = 1$)[17] and when $\phi \geq \phi^{CP}$ they collapse to them. We then have three kinds of stable locational equilibria: 1) a symmetric equilibrium (for $\phi \leq \phi^{cat}$) where $s_K = 1/2$; 2) two interior non-symmetric equilibria where s_K can take any value as ϕ^{cat} approaches ϕ^{CP}; 3) two core-periphery equilibria where $s_K = 0$ or $s_K = 1$ according to the initial condition or to the particular self-fulfilling expectations[18].

It is important to notice that, in steady state, the growth rate of the world capital stock K^w (or of the number of varieties n^w) will be constant and will either be common ($g = g^*$ in any interior equilibrium where $s_K \in (0,1)$) or North's g (in the core-periphery case). In fact, by time-differentiating $s_K = \frac{K}{K^w}$, we obtain that the dynamics of the share of manufacturing firms allocated in the North is:

$$\dot{s}_K = s_K \left(1 - s_K\right) \left(\frac{K}{K} - \frac{K^*}{K^*} \right) \tag{32}$$

so that only two kinds of steady-state ($\dot{s}_K = 0$) are possible: 1) a steady-state in which the rate of growth of capital is equalized across countries ($g = g^*$) 2) a steady-state in which the manufacturing industries are allocated and grow in only one region ($s_K = 0$ or $s_K = 1$). As a consequence, for any interior allocation to be an equilibrium ($s_K \in (0,1)$), the growth rate of capital in the two regions should be equal. We are now ready to face the analysis of growth patterns of our economy.

4 Growth Analysis

Although services play no role in the dynamics of spatial distribution of industrial firms, they become crucial when we analyze the growth patterns of the two regions. We will show that the introduction of a non-tradable sector which enjoys localized intersectoral knowledge spillovers from the cumulative output of the innovation sector leads to significant departures from the standard NEGG models both at the aggregate and at the regional level.

4.1 The Growth Rate of Knowledge Capital

The first step is to find the expression for the growth rate of capital units in both regions and for both the interior and the core-periphery equilibria. To do this, we need to define the labor market equilibrium. We remind that workers are mobile across sector but immobile across regions. They can be occupied either in the innovation sector, in manufacture, in services or in the traditional sector. In any case the world sectoral consumers' expenditure should be equal to the sectoral value of total production, so that:

$$L_M + L_M^* = \alpha E^w \frac{\sigma - 1}{\sigma} \tag{33}$$

$$L_T + L_T^* = \beta E^w \tag{34}$$

$$L_S + L_S^* = \gamma E^w \tag{35}$$

$$L_I + L_I^* = \frac{g s_K}{A} + \frac{g^* \left(1 - s_K\right)}{A^*} \tag{36}$$

Hence the labor market condition requires that:

$$L_T + L_T^* + L_M + L_M^* + L_S + L_S^* + L_I^* + L_I = \beta E^w + \alpha E^w \frac{\sigma - 1}{\sigma} + \gamma E^w + \frac{g s_K}{A} + \frac{g^* \left(1 - s_K\right)}{A^*} \tag{37}$$

[17] For $s_K = 1$ to be an equilibrium, accumulation should be profitable in the North but not in the South so no Southern agent would choose to setup a new firm. Defining the core-periphery equilibrium this way, it implies that it is stable whenever it exists.

[18] Again, see Baldwin *et al.* (2001) for a detailed explanation.

Consumers set expenditure at the permanent income hypothesis level in steady state. That is, they consume labor income plus ρ times their steady-state wealth, $FK = \frac{s_K}{A}$ and $F^*K^* = \frac{(1-s_K)}{A^*}$ in the North and in the South respectively. Hence $E = L + \rho\frac{s_K}{A}$ and $E^* = L + \rho\frac{(1-s_K)}{A^*}$. By summing up we find the expression for the world expenditure:

$$E^w = 2L + \rho\left(\frac{s_K}{A} + \frac{1-s_K}{A^*}\right) \tag{38}$$

Finally, substituting in the labor market clearing condition, considering that in steady state the growth rate is either common to the two regions ($g = g^*$) or equal to North's g and given that $L_T + L_T^* + L_M + L_M^* + L_S + L_S^* + L_I^* + L_I = 2L$ we find the equilibrium value of the growth rate of capital for any equilibrium spatial distribution of firms:

$$g(s_K) = \frac{2\alpha LAA^*}{\sigma(s_K A^* + (1-s_K)A)} - \frac{\sigma-\alpha}{\sigma}\rho \tag{39}$$

Again[19], the presence of a non-tradable sector does not affect the growth rate of capital, which is equal to the standard case. As in Baldwin *et al.* (2001), this rate of growth depends on the location of firms. By substituting for the value of A and A^* we find:

$$\frac{\partial g(s_K)}{\partial s_K} = \frac{\left(1-\lambda^2\right)2L\frac{\alpha}{\sigma}\lambda(2s_K-1)}{\left(2s_K(1-\lambda) - 2s_K^2(1-\lambda) + \lambda\right)^2} \tag{40}$$

This derivative is positive when s_K is larger than 1/2, meaning that increasing the share of firms in the most-industrialized region is growth-enhancing. We can also notice that geography matters for growth only in the case of localized innovation spillovers. When spillovers are global ($\lambda = 1$), we have in fact $\frac{\partial g}{\partial s_K} = 0$.

The effect of geography on growth is all the more appreciated if we calculate the equilibrium growth rate for the symmetric ($s_K = \frac{1}{2}$) and for the core-periphery ($s_K = 1$) steady states. In this case we have:

$$g(s_K)|_{s_K=1/2} = g^*(s_K)|_{s_K=1/2} = \frac{(1+\lambda)L\alpha - \rho(\sigma-\alpha)}{\sigma} \tag{41}$$

$$g(s_K)|_{s_K=1} = \frac{2L\alpha - \rho(\sigma-\alpha)}{\sigma} \tag{42}$$

with clearly $g(s_K)|_{s_K=1} > g(s_K)|_{s_K=1/2}$.

4.2 The Growth of Nominal and Real Income

In our model the nominal income level is analogous to the standard NEGG one:

$$Y = L + \pi s_K K^w = L + \frac{\alpha E^w A}{\sigma}\left[\frac{s_E}{(s_K + (1-s_K)\phi)} + \frac{\phi(1-s_E)}{(\phi s_K + 1 - s_K)}\right] \tag{43}$$

$$Y^* = L + \pi^*(1-s_K)K^w = L + \frac{\alpha E^w A^*}{\sigma}\left[\frac{\phi s_E}{(s_K + (1-s_K)\phi)} + \frac{1-s_E}{(\phi s_K + 1 - s_K)}\right] \tag{44}$$

Accordingly, as in Martin and Ottaviano (1999) and Baldwin *et al.* (2001), the growth rates of nominal income are constant for any (interior or CP) steady state:

$$\frac{\dot{Y}}{Y} = \frac{\dot{Y}^*}{Y^*} = 0, \forall s_K \in [0,1] \tag{45}$$

[19]Thanks to the homogeneity of degree 1 of the utility function.

Intuitively, Y and Y^* are constant because the growth of capital is perfectly compensated by the reduction in profits π and π^* which decrease at the same rate g. As a consequence, regional nominal income levels never diverge. Once again then, services do not affect nominal income growth rate.

However, unlike the benchmark model without services, the spatial distribution of manufacturing firms significantly affects the aggregated and regional growth rate of *real* income once our non-tradable sector is taken into account. Our S-sector has two main consequences on the growth patterns of regional and aggregate real incomes. First, intersectoral knowledge spillovers (localized or not) introduce a *pro-growth effect of dispersion*: when agglomeration takes place, the productivity loss of the S-sector in the deindustrialized region has a negative effect on aggregate and regional real growth. This negative effect may offset the positive effect of agglomeration given by the reduced innovation cost. When this is the case, agglomeration is bad for growth. Second, when spillovers are localized, the deindustrialized region suffers from a dynamic loss associated to the slower productivity growth of its S-sector and therefore, thanks to its non-tradability, regional growth rates of real incomes always diverge when agglomeration takes place.

To see this in detail, consider the Northern and Southern perfect price indexes associated to the second stage Cobb-Douglas utility function which are given by:

$$P = \frac{P_M^\alpha p_T^\beta p_S^\gamma}{\alpha^\alpha \beta^\beta \gamma^\gamma} \tag{46}$$

$$P^* = \frac{P_M^{*\alpha} p_T^{*\beta} p_S^{*\gamma}}{\alpha^\alpha \beta^\beta \gamma^\gamma} \tag{47}$$

Taking logs and differentiating we can decompose the growth rate of prices in both regions:

$$\frac{\dot{P}}{P} = \alpha\frac{\dot{P}_M}{P_M} + \beta\frac{\dot{p}_T}{p_T} + \gamma\frac{\dot{p}_S}{p_S} \tag{48}$$

$$\frac{\dot{P}^*}{P^*} = \alpha\frac{\dot{P}_M^*}{P_M^*} + \beta\frac{\dot{p}_T^*}{p_T^*} + \gamma\frac{\dot{p}_S^*}{p_S^*} \tag{49}$$

Northern and Southern real income levels are given by $\frac{Y}{P}$ and $\frac{Y^*}{P^*}$ respectively. The two growth rates of real income, $\varphi(s_K, K, K^*)$ and $\varphi^*(s_K, K, K^*)$ are then given by:

$$\varphi(s_K, K, K^*) = \frac{\dot{Y}}{Y} - \frac{\dot{P}}{P} = -\left(\alpha\frac{\dot{P}_M}{P_M} + \beta\frac{\dot{p}_T}{p_T} + \gamma\frac{\dot{p}_S}{p_S}\right) \tag{50}$$

$$\varphi^*(s_K, K, K^*) = \frac{\dot{Y}^*}{Y^*} - \frac{\dot{P}^*}{P^*} = -\left(\alpha\frac{\dot{P}_M^*}{P_M^*} + \beta\frac{\dot{p}_T^*}{p_T^*} + \gamma\frac{\dot{p}_S^*}{p_S^*}\right) \tag{51}$$

that is, in both regions, the growth rate of real income is given by the negative of the growth rate of prices. Finding the expressions for the growth rate of prices in the three sectors for both regions will shed light on how the allocation of manufacturing firms will affect aggregate and regional real income growth.

By log-differentiating (30) and (31) we find that the growth rate of manufacturing prices is always common for the two regions. That happens because the $M-$goods are traded across regions and therefore benefits of price reduction are enjoyed by the South as well even in the core-periphery outcome, when firms have no incentive to invest in the South:

$$\frac{\dot{P}_M}{P_M} = \frac{\dot{P}_M^*}{P_M^*} = -\frac{g\left(s_K\right)}{\sigma - 1} \tag{52}$$

Where the expression of $g\left(s_K\right)$ is given by (39).

Something similar happens with the price of the traditional good which, being our numeraire ($p_T = p_T^* = 1$), is constant in both regions by definition:

$$\frac{\dot{p}_T}{p_T} = \frac{\dot{p}_T^*}{p_T^*} = 0 \tag{53}$$

Finally, once we define the growth rate of the price of services we can appreciate the key departures from the benchmark model. Taking into account the fact that $w_S = w_S^* = 1$, the price of services in the two regions is given, respectively, by:

$$p_S = a_S(K, K^*) \tag{54}$$

$$p_S^* = a_S^*(K, K^*) \tag{55}$$

Taking logs and differentiating we find that:

$$\frac{\dot{p}_S}{p_S} = g(s_K)\,\theta_K(K, K^*) + g^*(s_K)\,\theta_{K^*}(K, K^*) \leq 0 \tag{56}$$

$$\frac{\dot{p}_S^*}{p_S^*} = g(s_K)\,\theta_K^*(K, K^*) + g^*(s_K)\,\theta_{K^*}^*(K, K^*) \leq 0 \tag{57}$$

As we can see, unlike the previous goods, regional $S-$price dynamics may well differ as long as $\theta_{K^*}(K, K^*) = \theta_K^*(K, K^*) < \theta_K(K, K^*) = \theta_{K^*}^*(K, K^*)$ - i.e. intersectoral knowledge spillovers are localized. Furthermore, as long as the cross elasticities $\theta_{K^*}(K, K^*) = \theta_K^*(K, K^*)$ are different from zero - i.e. intersectoral spillovers are not perfectly localized - both regional $S-$price dynamics depend on both local *and* foreign growth rate of knowledge capital $g(s_K)$ and $g^*(s_K)$.

After exploiting the symmetry of the spillover matrix, we substitute all the sectoral growth rate of prices in the expressions for the regional growth rates of real income to obtain[20]:

$$\varphi(s_K, K, K^*) = \underbrace{\frac{\alpha g(s_K)}{\sigma - 1}}_{\text{M-price effect}} - \underbrace{\gamma g(s_K)\,\theta_K(K, K^*)}_{\text{Home (North) S-price effect}} - \underbrace{\gamma g^*(s_K)\,\theta_{K^*}(K, K^*)}_{\text{Foreign (South) S-price effect}} \tag{59}$$

$$\varphi^*(s_K, K, K^*) = \underbrace{\frac{\alpha g(s_K)}{\sigma - 1}}_{\text{M-price effect}} - \underbrace{\gamma g^*(s_K)\,\theta_K(K, K^*)}_{\text{Home (South) S-price effect}} - \underbrace{\gamma g(s_K)\,\theta_{K^*}(K, K^*)}_{\text{Foreign (North) S-price effect}} \tag{60}$$

These expressions represent the central issue of our paper and deserve some comments.

First, it is important to highlight that, when $\gamma = 0$, these values collapse to the standard case described in Baldwin *et al.* (2001).

Second, since all elasticities are negative, we have that the growth rate of each regional real income can be viewed as the sum of *three* non-negative distinct elements:

1. **The $M-$price effect:** this effect is represented by the term $\frac{\alpha g(s_K)}{\sigma-1}$, it is the same for the two regions and (see (40)) it is larger the farther s_K is from $\frac{1}{2}$, (i.e., the more concentrated is industry in space) and it is maximum when $s_K = 0$ or $s_K = 1$. Hence, according to this effect, which is the only one found in the standard NEGG literature, *agglomeration is good for growth both at the regional and aggregate level.*

[20] One might observe that what really matters is welfare dynamics, not real income growth. However, in this case, welfare and real income always grow at the same rate in steady state. Welfare in the North is measured by $u(C_t) = \ln C_t^\alpha C_t^\beta C_t^\gamma$ which is equal to $\ln\left(\frac{E}{P}\right)$. By differentiating it we find:

$$\frac{\dot{E}}{E} - \frac{\dot{P}}{P} = r - \rho + \varphi(s_K, K, K^*) \tag{58}$$

Since, as already said, $r = \rho$ in steady state, we find that also welfare growth is equal to $\varphi(s_K, K, K^*)$.

2. **The home $S-$price effect:** this effect is represented by the term $-\gamma g(s_K)\theta_K(K,K^*)$ in the North and by the term $-\gamma g^*(s_K)\theta_K(K,K^*)$ in the South. It differs across regions as long as $g(s_K) \neq g^*(s_K)$ - i.e. in any core-periphery equilibrium or along the transitional dynamics to a new equilibrium where industry is more concentrated in space. This effect captures the dynamic gain enjoyed by the local non-tradable sector productivity from the growth of *local* knowledge capital or, which is the same, from the growth of the *local* industrial sector. As a consequence, this effect introduces an *anti-growth effect of agglomeration for the deindustrializing region* and *a pro-growth effect of agglomeration for the industrializing region.*

3. **The foreign $S-$price effect:** this effect is represented by the term $-\gamma g^*(s_K)\theta_{K^*}(K,K^*)$ in the North and by the term $-\gamma g(s_K)\theta_{K^*}(K,K^*)$ in the South. Again, it differs across regions as long as $g(s_K) \neq g^*(s_K)$ - i.e. in any core-periphery equilibrium or along the transitional dynamics to a new equilibrium where industry is more concentrated in space. It also differs from the **home $S-$price effect** as long as $|\theta_{K^*}(K,K^*)| < |\theta_K(K,K^*)|$ - i.e. intersectoral knowledge spillovers are localized. When knowledge spillovers are perfectly localized - i.e. $\theta_{K^*}(K,K^*) = 0$ - this effect is nil. It captures the dynamic gain benefited by the local non-tradable sector productivity from the growth of *foreign* knowledge capital or, which is the same, from the growth of the *foreign* industrial sector. As a consequence, this effects introduces an *anti-growth effect of agglomeration for the industrializing region* and *a pro-growth effect of agglomeration for the deindustrializing region.*

In the next sections we will give an answer to the following questions:

1. Can agglomeration reduce the aggregate growth rate of real income and when?

2. Can agglomeration reduce the growth rate of real income in the *periphery* and when?

3. Can agglomeration reduce the growth rate of real income in the *core* and when?
   And finally:

4. Can the regional real incomes diverge and when?

In the standard NEGG literature, the answer to all these questions is clear: "No. Never". This rather optimistic role of agglomeration, which as we have seen is by no means clearly supported by the empirical evidence, is here challenged even by the analytical point of view. As we can see, the introduction of our $S-$sector makes regional and aggregate growth patterns far more complex than in the benchmark model. We will identify the conditions according to which the answers to any of the previous questions is "yes" or "no". Such conditions will clearly depend on the interplay between the three effects described above. We will start by answering the fourth question.

4.3 Divergence of regional real incomes

A first relevant departure from the NEGG literature emerges when we compare the growth rate of real income *between* the two regions for a *given* degree of agglomeration. As already anticipated, although when agglomeration takes place knowledge capital stock may grow at different rates in the two regions, in standard NEGG models regional real incomes *always* grow at the same rate for any firms' allocation. The reason that happens, is because of a "terms of trade effect". Thanks to technological progress in the industrial sector, the price index of the manufacturing goods decreases faster than the price of the agricultural goods. This implies that the relative value of the commodity which the periphery specializes in — traditional goods — increases overtime making the periphery's imports of manufacturing goods cheaper. As a result, the real income of the periphery grows, in the long-run, at the same rate of the core. This figure changes dramatically when the interaction with our S - sector is taken into account. Let's see it in detail.

As we have seen, $g(s_K) = g^*(s_K)$ in any interior equilibria. Hence:

$$\varphi(s_K, K, K^*) = \varphi^*(s_K, K, K^*) = g(s_K)\left(\frac{\alpha}{\sigma-1} - \gamma\left(\theta_K(K, K^*) + \theta_{K^*}(K, K^*)\right)\right), \forall s_K \in (0,1) \quad (61)$$

Then, in any interior equilibria, there is no gap in the regional rate of growth of real income: when $s_K \in (0,1)$ our extension of Baldwin *et al.* (2001) confirms the conclusion of the benchmark model. Moreover, since the real growth rate depends on the location of industry only through $g(s_K)$, and we know that $g(\cdot)$ is increasing (decreasing) in s_K when $s_K > (<)\frac{1}{2}$, the positive relation between agglomeration and growth is confirmed too.

Things are significantly different in the core-periphery equilibrium which, we remind, turns out to be a stable one for any $\phi > \phi^{CP}$. Let's concentrate on $s_K = 1$ (the case $s_K = 0$ can be easily deduced being perfectly symmetric to the former). In this case we have that $g(1) > g^*(1) = 0$ so that the Southern service sector cannot benefit from internal intersectoral spillovers belonging to the local industry sector. Therefore:

$$\varphi(1, K, K^*) = g(1)\left(\frac{\alpha}{\sigma-1} - \gamma\theta_K(K, K^*)\right) \quad (62)$$

$$\varphi^*(1, K, K^*) = g(1)\left(\frac{\alpha}{\sigma-1} - \gamma\theta_{K^*}(K, K^*)\right) \quad (63)$$

so that, given that intersectoral spillovers are localized, there is a permanent positive gap between growth in Northern and Southern real income given by:

$$\varphi(1, K, K^*) - \varphi^*(1, K, K^*) = \gamma g(1)\left(\theta_{K^*}(K, K^*) - \theta_K(K, K^*)\right) > 0 \quad (64)$$

This proves the following

Proposition 1 *(Real growth differentials between regions) When intersectoral knowledge spillovers are localized - i.e.* $|\theta_{K^*}(K, K^*)| < |\theta_K(K, K^*)| \ \forall (K, K^*)$ *- then regional growth rate of real incomes differs when agglomeration takes place, being lower in the periphery. That is, for any* (K, K^*)

$$\varphi(1, K, K^*) > \varphi^*(1, K, K^*) \Leftrightarrow |\theta_K(K, K^*)| > |\theta_K(K, K^*)| \quad (65)$$

When intersectoral knowledge spillovers are global - i.e. $|\theta_{K^*}(K, K^*)| = |\theta_K(K, K^*)| \ \forall (K, K^*)$ *- there is no real growth differential between regions for any degree of agglomeration.*

Hence, unlike the benchmark model, in our extension the core-periphery equilibria is characterized by an ever-increasing real income differential between North and South and the latter may suffer from both a static and dynamic loss from agglomeration of firms in the North.

What is the economic intuition behind this result? The transmission mechanism works through the (negative) growth rate of the aggregate price index. Imagine we are moving from the symmetric equilibrium to another equilibrium (interior or CP) where industry is more concentrated in the North ($s_K > \frac{1}{2}$). As we have already seen, this will increase the growth rate of capital units but it will not affect the growth rate of nominal income which is nil for any s_K. However, following the increase in the Northern capital stock K, because of localized intersectoral spillovers, Northern $S-$sector will be able to produce the non-tradable goods at a lower cost with respect to Southern S-firms. Since services are non-tradable, the price of Southern services will then be higher. As long as the growth rate of capital is common to both regions (i.e. for any interior equilibria), this will only have an effect on the *level* of prices (leading to static losses for the periphery), but not on its growth rate. Nevertheless, in the core-periphery equilibrium, Northern growth rate of capital is $g(1)$ while Southern growth rate is $g^*(1) = 0$ because no firm has incentive to invest in the South. As a consequence, because of localized intersectoral spillovers from the manufacturing sector, the price of Northern services will decrease faster than the price of Southern services and this growth gap in $S-$goods price dynamics will not be filled because there is no integrated market for S-goods. This permanent gap in the growth rate of prices clearly has a consequence in the regional growth rate of real income which, in the core-periphery equilibrium, is permanently higher in the North.

It is important to highlight that regional real growth differentials, being highly connected to the fact that $g^*(s_K) = 0$, are not limited to the core-periphery outcome but they also emerge during the transitional dynamics to any new equilibrium where industry is more concentrated in the North. When this is the case, $g^*(s_K)$ is also zero while $g(s_K)$ is strictly positive.

Quite intuitively, the more spillovers are localized, the larger the gap. When spillovers are perfectly localized, $\theta_{K^*}(K, K^*) \equiv 0$, so that the gap is maximized. Moreover, the regional real growth gap positively depends on γ, which represents the relevance given by agents to services. From this viewpoint, if we imagine an increase of γ compatible with a widely accepted stylized fact about structural change and development phase, we should conclude that our model predicts that agglomeration policies leads to ever-increasing regional real growth gap as development advances.

4.4 The effect of agglomeration on regional and aggregate real growth

The second deviation from the NEGG literature emerges when we compare the growth rate of real income *within* the same region - or within the whole economy - with respect to different degrees of industrial agglomeration. So imagine that a hypothetical central planner wants to choose between the symmetric and the core-periphery equilibrium in order to maximize the growth rate of real income at the aggregate level[21]. By analyzing his choice we will answer to the first three questions of section 4.2.

For any equilibrium allocation s_K, aggregate real growth is just the weighted sum of the growth rate in the two regions, the weight being $\frac{1}{2}$ because regions are perfectly symmetric. In any interior equilibrium $s_K \in (0,1)$ then, the aggregate real growth rate is simply given by the common real growth rate so that:

$$\varphi(s_K, K, K^*) = \varphi^*(s_K, K, K^*) = \bar{\varphi}(s_K, K, K^*) = g(s_K)\left(\frac{\alpha}{\sigma-1} - \gamma\left(\theta_K(K, K^*) + \theta_{K^*}(K, K^*)\right)\right) \tag{66}$$

where $\bar{\varphi}(s_K, K, K^*)$ is the aggregate growth rate of real income. In particular, in the symmetric equilibrium we have that:

$$\varphi\left(\frac{1}{2}, K, K^*\right) = \varphi^*\left(\frac{1}{2}, K, K^*\right) = \bar{\varphi}\left(\frac{1}{2}, K, K^*\right) = g\left(\frac{1}{2}\right)\left(\frac{\alpha}{\sigma-1} - \gamma\left(\theta_K(K, K^*) + \theta_{K^*}(K, K^*)\right)\right) \tag{67}$$

[21] The choice of any other equilibrium might be difficult to justify because any other equilibrium will be stable for one and only one value of ϕ, while both the symmetric and the core-periphery equilibrium will be stable for an entire interval (respectively $\left[0, \phi^{cat}\right]$ and $\left[\phi^{CP}, 1\right]$) and then for infinite values of ϕ. Therefore, since the hypothetical central planner may affect the equilibrium dynamics through measures that have an effect on ϕ, when choosing between the symmetric and the core-periphery equilibrium, he actually chooses among two intervals of ϕ. By contrast, when choosing among any other interior equilibria, he chooses among *single values* of ϕ, thereby facing a much larger probability of making the wrong choice.

By contrast, in the CP equilibrium where $g(1) > g^*(1) = 0$, we have:

$$\varphi(1, K, K^*) = g(1)\left(\frac{\alpha}{\sigma-1} - \gamma\theta_K(K, K^*)\right) \tag{68}$$

$$\varphi^*(1, K, K^*) = g(1)\left(\frac{\alpha}{\sigma-1} - \gamma\theta_{K^*}(K, K^*)\right) \tag{69}$$

$$\bar{\varphi}(1, K, K^*) = \frac{\varphi(1, K, K^*) + \varphi^*(1, K, K^*)}{2} = g(1)\left(\frac{\alpha}{\sigma-1} - \gamma\frac{(\theta_K(K, K^*) + \theta_{K^*}(K, K^*))}{2}\right) \tag{70}$$

for the North, the South and the whole economy respectively. Notice that, in any case, North, South and aggregate real growth are increasing in the intensity of intersectoral knowledge spillovers whatever their degree of globalization.

The answers for the three previous questions is then the simple result of three comparisons between growth rate of real income in each area (North, South and the whole economy) computed in the core-periphery equilibrium and the same (common) growth rate computed in the symmetric equilibrium. To keep things simple, and without losing generality, we assume a constant elasticity[22] form for both $a_S(K, K^*)$ and $a_S^*(K, K^*)$ such that all elasticities are constant for any value of (K, K^*). We then have, for any (K, K^*):

$$\theta_K(K, K^*) = \theta_K < 0 \tag{72}$$

$$\theta_{K^*}(K, K^*) = \theta_{K^*} < 0 \tag{73}$$

In this case, the results of the three comparisons yield:

$$\varphi\left(\frac{1}{2}\right) > \varphi(1) \Leftrightarrow \gamma\frac{g(1)\,\theta_K - g\left(\frac{1}{2}\right)(\theta_K + \theta_{K^*})}{g(1) - g\left(\frac{1}{2}\right)} > \frac{\alpha}{\sigma-1} \tag{74}$$

$$\varphi^*\left(\frac{1}{2}\right) > \varphi^*(1) \Leftrightarrow \gamma\frac{g(1)\,\theta_{K^*} - g\left(\frac{1}{2}\right)(\theta_K + \theta_{K^*})}{g(1) - g\left(\frac{1}{2}\right)} > \frac{\alpha}{\sigma-1} \tag{75}$$

$$\bar{\varphi}\left(\frac{1}{2}\right) > \bar{\varphi}(1) \Leftrightarrow \gamma\frac{g(1)\,\frac{(\theta_K+\theta_{K^*})}{2} - g\left(\frac{1}{2}\right)(\theta_K + \theta_{K^*})}{g(1) - g\left(\frac{1}{2}\right)} > \frac{\alpha}{\sigma-1} \tag{76}$$

By considering that $|\theta_K| \geq |\theta_{K^*}|$, it is easy to see that these conditions imply:

$$\varphi\left(\frac{1}{2}\right) > \varphi(1) \Rightarrow \bar{\varphi}\left(\frac{1}{2}\right) > \bar{\varphi}(1) \Rightarrow \varphi^*\left(\frac{1}{2}\right) > \varphi^*(1) \tag{77}$$

However, when spillovers are global ($|\theta_K| = |\theta_{K^*}|$), the three conditions are identical because in this case, as stated in proposition 1, $\varphi(s_K) = \varphi^*(s_K) = \bar{\varphi}(s_K)$ for any $s_K \in [0, 1]$. Hence:

$$\varphi\left(\frac{1}{2}\right) = \varphi^*\left(\frac{1}{2}\right) = \bar{\varphi}\left(\frac{1}{2}\right) > \varphi(1) = \varphi^*(1) = \bar{\varphi}(1) \Leftrightarrow -\gamma\theta_K\frac{2g\left(\frac{1}{2}\right) - g(1)}{g(1) - g\left(\frac{1}{2}\right)} > \frac{\alpha}{\sigma-1} \tag{78}$$

This proves the following

Proposition 2 *(Growth effects of agglomeration at the regional and aggregate level) Agglomeration negatively affects the growth rate of real income in the North, in the South and in the whole economy according to conditions stated, respectively, in (74), (75) and (76).*

[22] A functional form of this kind would then be

$$a_S(K, K^*) = ZK^{\theta_K}K^{*\theta_{K^*}} \tag{71}$$

with Z constant positive parameter and θ_K and θ_{K^*} taking constant negative values.

When intersectoral knowledge spillovers are local, agglomeration has different impacts at the regional and aggregate level: a dynamic loss from agglomeration in the North implies a dynamic loss from agglomeration for the whole economy which implies a dynamic loss from agglomeration in the South, but not vice-versa. However, when intersectoral knowledge spillovers are global, agglomeration has the same negative impact both at the aggregate and regional level and it is detrimental to growth in the North, in the South and in the whole economy whenever condition (78) holds.

4.4.1 Discussion

This proposition identifies the conditions for agglomeration to be growth-detrimental both at the regional and at the aggregate level. This gives a far less optimistic role to agglomeration in our model with respect to the literature.

The role of γ, the expenditure share on non-tradable goods, is very clear and analogous in the three cases: provided that the numerators in the LHS of (74), (75) and (76) are positive (negative), an increase in γ helps these conditions to be fulfilled (unfulfilled) and enhances the positive (negative) effect of dispersion on regional and aggregate growth.

The next step is then to understand when the numerators in the LHS of (74), (75) and (76) are positive or negative. As already anticipated, the effect of agglomeration on regional and aggregate growth crucially depends on the interplay between three effects: the $M-$price effect, the home $S-$price effect and the foreign $S-$price effect. Consider expressions (59) and (60). When agglomeration takes place in the North, these expressions become:

$$\varphi(1) = \underbrace{\frac{\alpha g(1)}{\sigma-1}}_{\text{M-price effect}} - \underbrace{\gamma g(1)\,\theta_K}_{\text{Home S-price effect}} - \underbrace{0}_{\text{Foreign S-price effect}} \tag{79}$$

$$\varphi^*(1) = \underbrace{\frac{\alpha g(1)}{\sigma-1}}_{\text{M-price effect}} - \underbrace{0}_{\text{Home S-price effect}} - \underbrace{\gamma g(1)\,\theta_{K^*}}_{\text{Foreign S-price effect}} \tag{80}$$

It is then clear in which cases agglomeration might be bad for regional and aggregate growth.

First consider the North: when $s_K = 1$ both the M-price effect and the home $S-$price effect increase because $g(1) > g\left(\frac{1}{2}\right)$. In other words, real growth is enhanced by agglomeration for two different reasons: 1) innovation cost is reduced and this leads to a faster decrease in the price of $M-$ goods 2) the Northern $S-$sector productivity dynamics benefit from a faster growth of local knowledge capital. However, as long as intersectoral knowledge spillovers are not perfectly localized ($|\theta_{K^*}| > 0$), agglomeration in the North has also a negative effect on Northern growth: when agglomeration takes place, the foreign $S-$price effect (which is positive and equal to $-\gamma g\left(\frac{1}{2}\right)\theta_{K^*}$ in the symmetric case) goes to zero because the North cannot benefit from positive spillovers coming from a growing foreign knowledge capital. If θ_{K^*} is large enough and $g\left(\frac{1}{2}\right)$ is not much smaller than $g(1)$, then the negative effect of agglomeration on Northern real growth might even overcome its positive effects, then leading to a net dynamic loss. When this is the case, local industrialization is paradoxically detrimental to local growth.

The reason why agglomeration might be bad for Southern real growth is a bit more straightforward. Again, Southern real growth is boosted by agglomeration in the North for two different reasons: 1) innovation cost is reduced and this leads to a faster decrease in the price of $M-$ goods (produced in the North but also traded in the South) 2) as long as intersectoral spillovers are not perfectly localized the Southern $S-$sector productivity dynamics also benefits from a faster growth of Northern knowledge capital. However, agglomeration in the North means deindustrialization in the South: when manufacturing firms have no incentive to invest in knowledge capital in the South, the home $S-$price effect (which is positive and equal to $-\gamma g\left(\frac{1}{2}\right)\theta_K$ in the symmetric case) goes to zero. When θ_K is large enough and $g\left(\frac{1}{2}\right)$ is not too smaller than $g(1)$, then the negative effect of agglomeration on Southern real growth might well overcome its positive effects, then leading to a net dynamic loss in the South. When this is the case, local deindustrialization is detrimental to local growth.

Finally, the hypothetical dynamic loss at the aggregate level stems from a combination of these two outcomes: overall real growth is positively affected by agglomeration in the North for three reasons: 1) innovation cost is reduced 2) Northern and (to a lesser extent) 3) Southern $S-$goods price dynamics is positively affected by a faster growth of Northern knowledge capital. However, when agglomeration takes place in the North, aggregate real growth might be reduced because *both* Southern and (to a lesser extent) Northern $S-$ goods productivity cannot benefit from Southern investment in knowledge capital. Again, when θ_K, θ_{K^*} are large enough and $g\left(\frac{1}{2}\right)$ is not too far from $g(1)$, then it is more likely for agglomeration to be bad for aggregate growth.

But proposition 2 also tells us that, as long as $|\theta_K| > |\theta_{K^*}|$, the (negative or positive) impact of agglomeration on growth is different among regions and for the whole economy. In particular, it is more likely that agglomeration will be more harmful for the South because, when intersectoral spillovers are not global, the damage due to local deindustrialization (home $S-$price effect) is larger than the damage due to foreign deindustrialization (foreign $S-$price effect). As for aggregate real growth, the latter being simply the average between Southern and Northern growth, an aggregate loss from agglomeration in the North is more likely than a Northern loss and less likely than a Southern loss. In other words, three new options are possible when agglomeration takes place in the North: 1) a Southern dynamic loss with an aggregate and Northern dynamic loss 2) a Southern and aggregate dynamic loss with a Northern dynamic gain 3) a Southern, aggregate and Northern dynamic loss. The less localized spillovers are - i.e. the closest $|\theta_{K^*}|$ is to $|\theta_K|$ - the more equal the probability for each of these three outcomes to occur. In particular, when spillovers are global, only option 3 is possible while when spillovers are perfectly localized ($\theta_{K^*} = 0$), the North never loses from agglomeration.

5 Global efficiency and interregional equity

In this section, we will analyze in a more detailed way the condition according to which agglomeration is bad for growth at the aggregate level[23]. As already said, according to standard NEGG models, agglomeration is always good for long-run growth as there are no dynamic losses (for both the core and the periphery) associated to a higher degree of spatial concentration of industrial activities. Hence, the existence of a trade-off between interregional equity (in terms of spatial distribution of industrial activities and then knowledge capital) and global efficiency (in terms of aggregate growth of regional real incomes) is commonly accepted by the theoretical side of the NEGG literature. However, such common agreement on the role of agglomeration is not confirmed by the empirical evidence according to which the positive relation between agglomeration and aggregate growth appears to be limited to early stages of development.

As we have seen in proposition 2, the introduction of our non-tradable sector gives rise to some negative effect of agglomeration for both the periphery (the home $S-$price effect) and the core (the foreign $S-$price effect). When the dynamic losses from agglomeration associated to this effect are large enough, they offset the dynamic gains of agglomeration both at the regional and at the aggregate level. When this is the case, the trade-off between aggregate growth and interregional equity simply disappears.

[23] A similar analysis can also be performed to find the condition for agglomeration to be bad for growth in the North and in the South. However, for limited space, we do not perform this straightforward extension.

And interestingly our model predicts that such outcome, as the empirical evidence suggests, is more likely to be true in more advanced stages of development.

In order to see this more deeply, consider the expression (76) which states the condition for the trade-off between equity and efficiency to disappear. Such condition can be written as:

$$-\gamma\left(\theta_K+\theta_{K^*}\right)\left(g\left(\frac{1}{2}\right)-\frac{g\left(1\right)}{2}\right)>\frac{\alpha}{\sigma-1}\left(g\left(1\right)-g\left(\frac{1}{2}\right)\right) \tag{81}$$

which reveals that, the RHS being strictly positive, a necessary (but not sufficient) condition for agglomeration to be detrimental to aggregate growth is the LHS to be strictly positive as well. Since $\gamma\left(\theta_K+\theta_{K^*}\right)$ is negative, that happens when $\frac{g(1)}{2}<g\left(\frac{1}{2}\right)$ - i.e. the growth rate of knowledge capital in the symmetric equilibrium is larger than half of the growth rate of knowledge capital in the core-periphery outcome. It is clear how λ, the spatial range of intertemporal spillovers within the innovating sector, has a crucial role in this condition. By substituting for the expression for $g\left(1\right)$ and $g\left(\frac{1}{2}\right)$ ((42) and (41)) we obtain that:

$$\frac{g\left(1\right)}{2}<g\left(\frac{1}{2}\right)\Leftrightarrow\lambda>\frac{\rho\left(\sigma-\alpha\right)}{2L\alpha} \tag{82}$$

which tells us that λ should be large enough in order for the trade-off to disappear. This condition on λ is very important because, as expression (81) clearly shows, when it does not hold, the role of γ and $\left(\theta_K+\theta_{K^*}\right)$ is *reversed.*

If the term $\gamma\left(\theta_K+\theta_{K^*}\right)$ is not large enough, condition (82) is not sufficient for (81) to be true. Assuming (82) holds and by substituting for the value of $g\left(1\right)$ and $g\left(\frac{1}{2}\right)$ in (81), the latter becomes:

$$-\gamma\left(\theta_K+\theta_{K^*}\right)>\frac{2\left(1-\lambda\right)L\alpha^2}{\left(\sigma-1\right)\left(2\lambda L\alpha-\rho\left(\sigma-\alpha\right)\right)} \tag{83}$$

Condition (83) is the target of our analysis. It is easy to see that the RHS (whose positivity is granted by condition (82)) is *decreasing* in λ while the LHS is *increasing* in γ and in $\left|\theta_K+\theta_{K^*}\right|$. This proves the following

Proposition 3 *(The trade off between equity and efficiency) There is no trade-off between interregional equity and global efficiency when condition (82) and condition (83) hold. That happens when*

1. *the spatial range of intertemporal knowledge spillovers λ is* ***large enough*** *and necessarily larger than $\frac{\rho(\sigma-\alpha)}{2L\alpha}$*
2. *the expenditure share on non-tradable goods γ is* ***large enough***
3. *the absolute value of the sum of the home and foreign component of the intersectoral knowledge spillovers $\left|\theta_K+\theta_{K^*}\right|$ is* ***large enough***

This proposition deserves some comments. First of all, it states that our trade-off disappears when the *intrasectoral* technology spillovers are globalized enough. If we interpret λ in a historical perspective - along the lines of Martin (1999), Baldwin *et al.* (2001) - we should expect an overtime increase in the degree of globalization of technology spillovers as a result of the continuous progress in the technology of information diffusion (Keller (2002)). Hence, condition (83) predicts that the strength of the trade-off between aggregate growth and interregional equity is likely to lose importance and eventually disappear as time goes by. Moreover, if we accept (as Peri (2005) argues) that the spatial range of technological spillovers is larger in more developed and innovative countries, then condition (83) also predicts, once again in agreement with the empirical evidence, that the positive effect of agglomeration on aggregate growth is more likely to be a prerogative of developing countries while such positive effect is doomed to disappear, and eventually turn into a negative effect, with the process of economic development.

Second, the proposition states that, in order for the trade-off to disappear, non-tradable goods should be important enough for the representative consumer. As argued in section 2.2.1, the empirical evidence on structural change shows how such importance has been constantly increasing overtime at the world level in the last 30 years. Moreover, it is widely accepted that the importance of non-tradable services in the utility function is larger in more advanced stages of development. In other words, condition (83) predicts that the trade-off between interregional equity and global efficiency is more likely to exist in developing countries where services are less important. By contrast, agglomeration is more likely to slow down aggregate real growth in more developed countries. These considerations, together with the recent empirical findings which support the "Williamson hypothesis"- agglomeration boosts GDP growth only up to a certain level of economic development - suggest that the mechanism introduced in our model might be a good candidate to reconcile the theoretical and empirical counterparts of NEGG literature.

Finally, proposition 3 gives a crucial role to the intensity of home and foreign *intersectoral* spillovers, $(\theta_K + \theta_{K^*})$, which should be large enough in order for the trade-off to disappear. Intuition suggests that, if intersectoral and intrasectoral knowledge spillovers share a common nature, the behaviour of $(\theta_K + \theta_{K^*})$ across time and across countries might resemble λ's behaviour. In other words, $(\theta_K + \theta_{K^*})$ is expected to increase overtime and to be larger for more developed countries where knowledge diffusion is less constrained. If this is the case, condition (83) is once again consistent with the empirical evidence in its prediction that the relevance of the trade-off between interregional equity and global efficiency is more likely to lose relevance (and eventually to be reversed) along with the process of development[24].

5.1 A simple calibration exercise

To the best of our knowledge, there are no empirical studies aimed at measuring the elasticity of intersectoral spillovers between manufacture and non-tradables in a NEGG framework. Hence, to give an idea of the required magnitude of $(\theta_K + \theta_{K^*})$ for condition (83) to be true, we perform a simple calibration exercise as outlighted in table 2.

The last column of the table reports the implied minimum value of $|\theta_K + \theta_{K^*}|$ such that condition (83) is satisfied for some given values of the parameters σ, L, γ, ρ, α and λ. The reference value for each of these parameters (on the central row) are consistent with those usually chosen in the literature (see especially Martin and Ottaviano (1999)), while two other values for each parameter (smaller and larger than the reference value) are chosen in order to perform a sensitivity analysis which allows us to capture the relative importance of each parameter in condition (83). While the reference values of σ (4), L (2) and ρ (0.05) are quite standard in the literature, it is worth spending some words on the reference value chosen for γ, α and λ.

γ and α, representing respectively the expenditure share for the S and for the M goods, are strictly connected as their sum must be strictly smaller than unity (being $\gamma + \alpha + \beta = 1$). For these reason, their deviation from their reference values is jointly computed. The reference value chosen for these parameters - respectively 0.7 and 0.2 - are computed from the STAN database in order to fit a middle-income economy like Turkey, South Africa or Russia (see also fig. (1)). On the other hand, the values $\gamma = 0.8$ and $\alpha = 0.15$ and $\gamma = 0.5$ and $\alpha = 0.25$ fit to more developed and less developed countries

[24]Another important implication would be that (θ_{K^*}) is expected to increase faster than (θ_K) and to converge to the latter. As a consequence, intersectoral knowledge spillovers are expected to become less localized. If this is the case, by proposition 1 and 2, our model predicts that 1) regional growth differentials are expected to be larger for developing countries and to be reduced with the process of development and 2) the periphery and aggregate dynamic loss from agglomeration is more likely to decrease with the process of economic development

Table 2: Sensitivity Analysis

σ	**L**	γ	α	ρ	λ	$\lvert\theta_K + \theta_{K^*}\rvert$
...	...	...	...	...	0.4	0.35
...	...	...	...	0.2	...	0.08
...	...	0.5	0.25	...	...	0.16
...	2000000	...	...	...	...	0.06
3	...	...	...	...	...	0.13
4	2	0.7	0.2	0.05	0.6	0.11
5	...	...	...	...	...	0.10
...	20000000	...	...	...	...	0.06
...	...	0.8	0.15	...	...	0.09
...	...	...	...	0.08	...	0.17
...	...	...	...	...	0.8	0.03

respectively.

As for λ, an estimate which fits with the meaning of this parameter in our model cannot easily be found in the literature. Several works have tried to measure the degree of localization of knowledge spillovers, but since our model is highly stylized (only two regions with equal size) the interpretation of the resulting estimates are a bit different from our λ which represents, we remind, the "share of foreign knowledge capital which contributes to reduce the local cost of innovation". Two important empirical works on this subject are Peri (2005) and Keller (2002). Peri (2005) finds that only 20% of average knowledge is learned outside the average region of origin which suggests that, in an economy with only two regions, a plausible value for λ could be 0.2. However, the average actual region Peri (2005) refers to spills knowledge from several other regions, with or without sharing a border, and with different sizes. Hence, we conclude that a value of 0.2 would be underestimated. This conclusion is supported by Keller (2002) who finds that the productivity effect from foreign R&D is 20% larger than home R&D, suggesting a value of 1.2, which is not feasible in our model. Taking all these into account, and still being conservative with λ in order not to underestimate the implied values of $|\theta_K + \theta_{K^*}|$, we choose a reference value of 0.6, with 0.4 and 0.8 as lower and upper deviation.

The implied value for $|\theta_K + \theta_{K^*}|$ in the reference case is 0.11 meaning that, with the reference parameter values, a 100% increase of home and foreign knowledge capital should reduce the local S-sector production cost by at least 11% in order for agglomeration to be *bad* for aggregate growth of real income. By considering the deviations from the reference case, the implied values for $|\theta_K + \theta_{K^*}|$ range from 3,3% (with λ=0.8) to 35% (with λ=0.4), showing that condition (83), and therefore the existence or non-existence of the trade-off, is highly sentitive to the spatial range of intrasectoral knowledge spillovers. Although these implied values can hardly be compared with the existing estimates for the strength of intersectoral spillovers, we believe they are plausible values meaning that, if we trust the model, the trade-off between interregional equity and global efficiency might not exist for a wide range of actual economies.

6 Conclusions and Policy Implications

A robust implication of the theoretical side of the NEG literature is that, in the presence of intertemporal localized knowledge spillovers in the innovation sector, it is possible to increase the long-run aggregate economic growth and, at the same time, to leave it uniform across regions, by promoting policies aimed at favoring the agglomeration of the industrial sector in only one region. This theoretical statement encompasses four results: 1) agglomeration is always good for growth in the core region; 2) agglomeration is always good for growth in the peripheral region; 3) agglomeration is always good for growth at the aggregate level; 4) for any degree of agglomeration, the growth rates of regional real income are always the same.

These results, which are not supported by the empirical evidence, are challenged in our paper. By introducing intersectoral localized knowledge spillovers between innovation and the newly added service sector (a deviation for which we provide empirical support), we have shown that the growth effect of agglomeration is more puzzling. As this deviation generates both an anti-growth and a pro-growth effect of agglomeration for both the deindustrializing and the industrializing regions, we find that 1) regional growth rates of real income are always different when agglomeration takes place, being lower in the periphery; 2) agglomeration may have a negative effect on the growth rate of real income, *both* at the regional *and* at the aggregate level.

In particular, we have found that the trade-off between interregional equity (in terms of spatial allocation of firms) and global efficiency (in terms of growth rate of aggregate real income), loses relevance and is eventually reversed when: 1) the spatial range of the intrasectoral spillovers within the R&D sector; 2) the external benefit of local and foreign knowledge capital on non-tradable sector productivity 3) the expenditure share on non-tradable goods are *all* large enough. These findings are consistent with the recent empirical evidence which supports the "Williamson hypothesis"- agglomeration boosts GDP growth only up to a certain level of economic development. A simple calibration exercise shows that the minimum implied values of the intersectoral knowledge spillovers in order for agglomeration to be bad for growth are highly plausible. Hence, our paper provides a natural mechanism to reconcile theory with the empirical evidence, especially for advanced economies.

Considering the appeal that NEG theoretical statements have on policy-makers, we believe these results have strong policy implications as they suggest policy rules which, in some cases, are opposite from those recommended by the commonly accepted models like Martin (1999) and Baldwin *et al.* (2001): concentrating economic activities in only one region may be welfare-harming both at the regional *and* at the aggregate level and may generate ever-increasing regional income disparities.

Applying our implications to the EU case, our claim would be that European Regional Policies - which clearly favor industrial dispersion - may have a growth effect not only for the peripheral regions (as empirically evidenced by Busillo *et al.* (2010)) but also for the whole economy and even, quite surprisingly, for the core regions. Our model suggests that the likelihood of these conclusions increases with the level of economic development of the countries interested by such policies. It is important to highlight that, as long as integration is believed to strengthen concentration forces and to activate the agglomeration process, our conclusions also implies that, especially in more developed countries, integration policies might be bad for both regional and aggregate growth. An interesting line of research which might follow from this work is to join our analysis to a theoretical microfoundation and an empirical assessment of intersectoral knowledge spillovers and to a deeper investigation, along the lines of Murata (2008), of the mechanics of structural change by making the expenditure share on non-tradable goods an endogenous variable.

References

[1] Andres F., (2007), "Divergence, Wage-Gap and Geography", *Economie Internationale*, 4: 83-112.

[2] Audretsch D. and Feldman M., (2004), "Knowledge spillovers and the geography of innovation", in Henderson V. and J.F. Thisse (eds.) *Handbook of Regional and Urban Economics: Cities and Geography*, Amsterdam: Elsevier.

[3] Baldwin R., (1999), "Agglomeration and Endogenous Capital", *European Economic Review*, 43: 253-280.

[4] Baldwin R., Forslid R., (2000), "The Core-Periphery Model and Endogenous Growth: Stabilizing and De-Stabilizing Integration", *Economica*, 67: 307-324.

[5] Baldwin R., Forslid R., Martin P., Ottaviano G., Robert-Nicoud F. (2004), "Economic Geography and Public Policy", *Princeton: Princeton University Press.*

[6] Baldwin R., Martin P., (2004), "Agglomeration and Regional Growth", *Handbook of Regional and Urban Economics*, in: J. V. Henderson and J. F. Thisse (ed.), *Handbook of Regional and Urban Economics*, 2671-2711, Amsterdam: Elsevier.

[7] Baldwin R., Martin P., Ottaviano G., (2001), "Global Income Divergence, Trade, and Industrialization: The Geography of Growt Take-Offs", *Journal of Economic Growth*, 6: 5-37.

[8] Bartik, T., 2002, "Evaluating the Impacts of Local Economic Development Policies On Local Economic Outcomes: What Has Been Done and What is Doable?", *Upjohn Institute Staff Working Paper, No. 03-89.*

[9] Behrens K. (2004), "Agglomeration without trade: how non-traded goods shape the space-economy", *Journal of Urban Economics*, 55: 68-92.

[10] Bellone F., Maupertuis M., (2003), "Economic Integration and Regional Income Inequalities: Competing Dynamics of Regional Wages and Innovative Capabilities", *Review of International Economics*, 11: 512-526.

[11] Bhagwati J. N. (1984), "Why are services cheaper in the poor countries?", *The Economic Journal*, 94: 279-286.

[12] Blinder A. (2005), "Fear of Offshoring", *CEPS Working Paper No. 119.*

[13] Bruhlart M., Sbergami F., (2009), "Agglomeration and growth: Cross-country evidence", *Journal of Urban Economics*, 65: 48-63.

[14] Buera F. and Kaboski J., (2009), "Can Traditional Theories of Structural Change Fit The Data?", *Journal of the European Economic Association*, vol. 7(2-3), 469-477, 04-05.

[15] Busillo F., Muccigrosso T., Pellegrini G., Tarola O., Terribile F.,(2010), "Measuring the Impact of the European Regional Policy on Economic Growth: a Regression Discontinuity Design Approach", *Working Paper 6/2010, Dipartimento di Teoria Economica e Metodi quantitativi per le Scelte Politiche, Università di Roma Sapienza.*

[16] Cappelen, A., Castellacci, F., Fagerberg, J., Verspagen, B. (2003) "The Impact of EU Regional Support on Growth and Convergence in the European Union", *Journal of Common Market Studies*, 41(4): 621-43.

[17] Cerina. F., Pigliaru, F., (2007), "Agglomeration and Growth: a critical assessment"in Bernard Fingleton (ed.), 2007, *New Directions in Economic Geography*, Chelthenam: Edward Elgar.

[18] Cerina. F., Mureddu F., (2008) "Agglomeration and Growth with Endogenous Expenditure Shares", *Working Paper CRENoS 200820.*

[19] Dixit A.K., Stiglitz J.E., (1977), "Monopolistic Competition and optimum product diversity", *American Economic Review*, 67: 297-308.

[20] Dupont V. (2007), "Do geographical agglomeration, growth and equity conflicts?" *Papers in Regional Science*, 86: 193-213.

[21] Dupont V., Martin P., (2006), "Subsidies to poor regions and inequalities: some unpleasant arithmetic", *Journal of Economic Geography*, 6: 223-240.

[22] EU Commission, (2001), "Second Report on Economic and Social Cohesion", *Brussels, http://europa.eu.int./comm/ regional_policy/sources/docoffic/official/reports/contentpdf_enf.htm.*

[23] EU KLEMS Database, (2007), *http://www.euklems.net*

[24] Fujita M, Thisse J.F., (2003), "Does Geographical Agglomeration Foster Economic Growth? And Who Gains and Loses from It?", *The Japanese Economic Review*, 54: 121-145

[25] Gardiner, B., Martin, R., Tayler, P. (2004) "Competitiveness, Productivity and Economic Growth across the European Regions", *Regional Studies*, 38(9): 1045-67.

[26] Giannetti, M. (2002) "The Effects of Integration on Regional Disparities: Convergence, Divergence or Both?", *European Economic Review*, 46(3): 539-67.

[27] Glaeser E., Kallal H., Scheinkman J., Shleifer A., (1992), "Growth in Cities", *Journal of Political Economy*, vol. 100(6), 1126-52, December.

[28] Henderson, J. Vernon (2003), "The urbanization process and economic growth: The so-what question", *Journal of Economic Growth*, 8: 47-71.

[29] Henderson, J. Vernon, Shalizi, Zmarak, Venables, Anthony J., (2001), "Geography and development", *Journal of Economic Geography*, 1: 81-105.

[30] Kaiser U., (2002), "Measuring knowledge spillovers in manufacturing and services: an empirical assessment of alternative approaches", *Research Policy*, vol. 31(1), pages 125-144, January.

[31] Keller W., (2002), "Geographic Localization of International Technology Diffusion", *American Economic Review*, vol. 92(1), pages 120-142, March.

[32] Kongsamut P., Rebelo S., Xie D. (2001), "Beyond Balanced Growth", *Review of Economic Studies*, 68: 869-882.

[33] Krugman P., (1991), "Increasing Return and Economic Geography", *Journal of Political Economy*, 99: 483-99.

[34] Kuznets S., (1973), "Modern Economic Growth: Findings and Reflections", *American Economic Review*, vol. 63(3), pages 247-58, June.

[35] Martin P., (1999), "Public Policies, Regional Inequalities and Growth", *Journal of Public Economics*, 73: 85-105.

[36] Martin P., Ottaviano G., (1999), "Growing Locations: Industry Location in a Model of Endogenous Growth", *European Economic Review*, 43: 281-302.

[37] Martin P., Ottaviano G. (2001), "Growth and Agglomeration", *International Economic Review*, 42: 947-68.

[38] Murata Y., (2008), "Engel's law, Petty's law, and agglomeration", *Journal of Development Economics*, vol. 87(1), pages 161-177, August.

[39] OECD, (2007), "The STAN Database for Industrial Analysis", *http: www.oecd.org, 2007.*

[40] Paci, R., Pigliaru, F. (2002), "Technological Diffusion, Spatial Spillovers and Regional Convergence in Europe", *In Cuadrado-Roura, J., Parellada, M. (eds.) Regional Convergence in the European Union: Facts, Prospects and Policies. Heidelberg and New York: Springer.*

[41] Park J. (2004), "International and Intersectoral R&D Spillovers in the OECD and East Asian Economies", *Economic Inquiry*, 42: 739-757.

[42] Park S., Chan K. (1989), "A cross-country input-output analysis of intersectoral relationships between manufacturing and services and their employment implications", *World Development*, 17: 199-212.

[43] Peri G., (2005), "Determinants of Knowledge Flows and their Effect on Innovation", *Review of Economics and Statistics*, 87: 308-322.

[44] Potì B., Cerulli G. (2007) "Heterogeneity of innovation strategies and firms' performance", *CERIS Working Paper 200706.*

[45] Quella N., (2006), "Intra- and Inter-sectoral Knowledge Spillovers and TFP Growth Rates", *2006 Meeting Papers 431, Society for Economic Dynamics.*

[46] Puga D. (2002), "European regional policies in light of recent location theories", *Journal of Economic Geography*, 4: 373-406.

[47] Romer P., (1990), "Endogenous Technological Change", *Journal of Political Economy* 98: S71-S102.

[48] Sbergami F., (2002), "Agglomeration and Economic Growth: Some Puzzles", *HEI Working Paper No: 02/2002.*

[49] Tabuchi T. and Thisse J.F., (2002), "Regional Specialization and Transport Costs", *CEPR working paper*, n. 3542.

[50] van Meijl H., (1997), "Measuring the Impact of Direct and Indirect R&D on the Productivity Growth of Industries: Using the Yale Technology Concordance", *Economic Systems Research*, vol. 9(2), pages 205-11, June.

[51] Yamamoto K., (2002), "Agglomeration and growth with innovation in the intermediate goods sector", *Regional Science and Urban Economics*, 33: 335-60.

[52] Williamson J., (1965), "Regional inequality and the process of national development", *Economic Development and Cultural Change*, 13: 3-45.

[53] The World Bank (2007), "World Development Indicators 2008", *Washington, DC: The World Bank.*

Appendix: The Dynamic System Governing the Economy

Let's compute the law of motion for expenditure in the North. We start from the expression for the capital replacement cost in the North:

$$F = wa_I = \frac{1}{AK^w} = \frac{1}{(K + \lambda K^*)}$$

By time differentiation we have:

$$\dot{F} = -\frac{\dot{K} + \lambda \dot{K}^*}{(K + \lambda K^*)^2}$$

Now, using equations (1) and (4):

$$\dot{K} = \frac{L_I A}{s_K} K$$

$$\dot{K}^* = \frac{L_I^* A^*}{1 - s_K} K^*$$

Substituting in the expression for $\dot{F}$ we obtain:

$$\dot{F} = -\frac{1}{(K + \lambda K^*)^2} \left(\frac{L_I A}{s_K} K + \frac{\lambda L_I^* A^*}{1 - s_K} K^* \right) = -\frac{K^w}{(K + \lambda K^*)^2} \left(L_I A + \lambda L_I^* A^* \right)$$

As we know labor in the I-sector is equal to the value of investments (i.e. income minus expenditure) so it is given respectively in each region by:

$$L_I A = LA + \pi K A - EA = LA + \frac{E^w}{\sigma} B s_K A - EA$$

$$L_I^* A^* = LA^* + \frac{E^w}{\sigma} B^* (1 - s_K) A^* - E^* A^*$$

Moreover we know that:

$$A = s_K + \lambda (1 - s_K) = \frac{K + \lambda K^*}{K^w}$$

$$A^* = \lambda s_K + (1 - s_K) = \frac{\lambda K + K^*}{K^w}$$

Thus we can write:

$$\frac{\dot{F}}{F} = -L (1 + \lambda) \frac{(\lambda K + K^*)}{(K + \lambda K^*)} + \lambda E^* \frac{(\lambda K + K^*)}{(K + \lambda K^*)} + E - \frac{E^w}{\sigma} \left(B s_K - \lambda B^* (1 - s_K) \frac{(\lambda K + K^*)}{(K + \lambda K^*)} \right)$$

By substituting this last expression first in the no-arbitrage condition (equation (11)) and then in the Euler equation (equation (10)) we finally have:

$$\frac{\dot{E}}{E} = \frac{E^w}{\sigma} \left(AB - B s_K - \lambda B^* (1 - s_K) \frac{(\lambda K + K^*)}{(K + \lambda K^*)} \right) - L \left(1 + \lambda \frac{(\lambda K + K^*)}{(K + \lambda K^*)} \right) + \lambda E^* \frac{(\lambda K + K^*)}{(K + \lambda K^*)} + E - \rho$$

The expression for the South is symmetric:

$$\frac{\dot{E}^*}{E^*} = \frac{E^w}{\sigma} \left(A^* B^* - \lambda B^* (1 - s_K) - B s_K \frac{(\lambda K + K^*)}{(K + \lambda K^*)} \right) - L \left(1 + \lambda \frac{(\lambda K + K^*)}{(K + \lambda K^*)} \right) + \lambda E^* \frac{(\lambda K + K^*)}{(K + \lambda K^*)} + E - \rho$$

Concerning the law of motion of the capital location, from equation (17):

$$\dot{s}_K = s_K (1 - s_K) (g - g^*)$$

We then substitute equations (1) to (4) in order to find:

$$\dot{s}_K = s_K (1 - s_K) \left(\frac{L_I a_I}{s_K} - \frac{L_I^* a_I^*}{1 - s_K} \right)$$

Given the expressions for labor in the I-sector:

$$L_I = L + \pi K - E = L + \frac{E^w}{\sigma} B s_K - E$$

$$L_I^* = LA^* + \frac{E^w}{\sigma} B^* (1 - s_K) - E^*$$

We finally find:

$$\dot{s}_K = \left((1 - s_K) \left(L + \frac{E^w}{\sigma} B s_K - E \right) A - s_K \left(L + \frac{E^w}{\sigma} B^* (1 - s_K) - E^* \right) A^* \right)$$

The dynamic of our model is then described by three differential equations. We have two Euler equations (one for each region) representing the evolution of expenditure and another equation representing the evolution of capital location:

$$\frac{\dot{E}}{E} = \frac{E^w}{\sigma} \left(AB - Bs_K - \lambda B^* (1 - s_K) \frac{(\lambda K + K^*)}{(K + \lambda K^*)} \right) - L \left(1 + \lambda \frac{(\lambda K + K^*)}{(K + \lambda K^*)} \right) + \lambda E^* \frac{(\lambda K + K^*)}{(K + \lambda K^*)} + E - \rho$$

$$\frac{\dot{E}^*}{E^*} = \frac{E^w}{\sigma} \left(A^* B^* - \lambda B^* (1 - s_K) - Bs_K \frac{(\lambda K + K^*)}{(K + \lambda K^*)} \right) - L \left(1 + \lambda \frac{(\lambda K + K^*)}{(K + \lambda K^*)} \right) + \lambda E^* \frac{(\lambda K + K^*)}{(K + \lambda K^*)} + E - \rho$$

$$\dot{s}_K = \left((1 - s_K) \left(L + \frac{E^w}{\sigma} B s_K - E \right) A - s_K \left(L + \frac{E^w}{\sigma} B^* (1 - s_K) - E^* \right) A^* \right)$$

These equation are identical to those which characterize the stability of the system in Baldwin *et al.* (2001). Hence the introduction of the S-sector does not affect the stability of the locational equilibria.