The (strong) interdependence between intermediate producer services' attributes and manufacturing location

Luis Lanaspa[a], Fernando Sanz-Gracia[a] and María Vera-Cabello[b,1]

[a] Departamento de Análisis Económico, Facultad de Economía y Empresa, Gran Vía 2, 50005 Zaragoza, Spain

[b] Centro Universitario de la Defensa, Academia General Militar, Carretera de Huesca s/n, 50090 Zaragoza, Spain

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ABSTRACT

The empirical evidence shows that a high degree of co-location exists between intermediate producer services and manufacturers. This paper develops a theoretical model based on the Footloose Entrepreneur Model of the New Economic Geography in which intermediate producer services play an essential role in characterizing the industrial landscape. Our results show that the concentration of manufacturing is favored when the service sector has high price elasticity for any variety and is a very efficient sector in production and when the mobile–fixed factor, skilled workers, is important in the production of manufacturing. In a nutshell, to promote economic activity, the industrial policy and service sector policy should be coordinated.

KEYWORDS: intermediate producer services, manufacturing concentration, co-location

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[1] Corresponding author.
E-mail address: mvera@unizar.es
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1. INTRODUCTION

In modern economies the service sector is essential, not only quantitatively but also qualitatively, and its importance is increasing. In effect, according to data from the World Bank, the service industry contributed 70.1% of the world GDP in 2012, while the figure was scarcely above 50% in the early 1970s. The global importance of the sector is accentuated if we focus on the most developed economies; in 2012 it represented 77.7% in the United States of America and 73.9% in the European Union, reaching 86.1% of the GDP of Luxembourg. Indeed, the relative importance of services in the GDP can be considered an indirect but useful indicator of the degree of a country's development and quality of life. Moreover, the growth in India, China and some other economies in South-East Asia can be attributed to a certain extent to growth in intermediate producer service activities (Bosworth and Collins, 2008; Tseng and Cowen, 2013).

What is so special about services that makes them strategic goods? First, by definition, services have special characteristics that most goods do not share. They are labor intensive; they are, to a certain extent, intangible goods; and, finally, they tend to be luxury goods. Second, intermediate producer services can generate gains in productivity in the manufacturing sector (Amiti and Wei, 2009; Baker, 2007; Greenhalg and Gregory (2001); Hansen, 1990; Kox and Rubalcaba, 2007; Léo and Philippe, 2005). Third, in recent decades manufacturers have gradually changed their organizational strategies from vertically integrated activities to outsourcing. This externalization has especially affected knowledge-intensive business services (KIBSs), which do not include business services such as outsourcing activities located in other countries. The intermediate producers of services may be able to exploit scale economies, supplying these services in a specific and particularized way (differentiated intermediate producer services).

Against this background, we incorporate the service sector into a standard theoretical New Economic Geography (NEG) model, the Footloose Entrepreneur Model of Forslid and Ottaviano (2003, FO hereafter), with special emphasis on its role as an intermediate input for the manufacturing sector. To the FO framework, our model adds an intermediate producer service sector that is differentiated by a monopolistic competition market structure and produces with increasing returns. Moreover, the intermediate producer service sector is non-tradable and acts as a fixed input for manufacturing production, using skilled labor (economists, engineers, lawyers, advertising and marketing experts, actuaries, insurance brokers) as its only production factor. In a nutshell, our model aims to explore and define how the incorporation of intermediate services affects the spatial configuration of the manufacturing equilibria.

The main links of our model with the previous theoretical literature are the following. A full consideration of the importance of services as intermediate inputs for manufacturing can be found in van Marrewijk et al. (1997), which is constructed mainly from the contributions of Ishikawa (1992) and Markusen (1989). In these papers services inputs are tradable and the emphasis is on the characteristics of the intermediate producer services and final goods trade and not on analyzing issues related to their location. However, Alonso-Villar and Chamorro-Rivas (2001) and de Vaal and van den Berg (1999) introduce intermediate services inputs into a typical economic geography model and, therefore, specifically discuss the problems related to the resulting spatial landscape. Both of these papers are based on the model of Krugman (1991) and thus rely on numerical simulations.

In this context our theoretical model of economic geography may be a step forward in the analysis of the effects that intermediate producer services have on the equilibrium of the industrial landscape in three ways. First, in our approach the intermediate producer services are non-tradable, a feature that, as far as we know, has received little treatment in the literature. Second, the model can be solved analytically, without requiring simulation. Third, it is derived from Forslid and Ottaviano (2003), which, as will be seen below, enables us to obtain very clear results regarding how the different parameters associated with the service sector influence the industrial landscape.

Our main results define when intermediate producer services act as a centripetal force encouraging the concentration of manufacturing. The characteristics of the intermediate producer service sector that tend to favor a more concentrated industrial landscape are a very productive service sector, a less differentiated service sector and a greater requirement of the mobile–fixed factor (skilled workers) in the production of manufactured goods.

The rest of the paper is structured as follows. The second section motivates our theoretical model from a practical and empirical point of view. The third section defines the basic model. The fourth section is the core of the paper and includes a comparative static analysis from which we deduce the three effects summarizing how the service sector affects industrial localization. The fifth section studies the number and stability of the resulting equilibria. Finally, the paper ends with our conclusions.

2. EMPIRICAL MOTIVATION OF OUR THEORETICAL EXERCISE

Before developing the model, in this section we show the empirical relevance of the research that we carry out, which is related to practical aspects of the real economic world. The main thesis that we want to present is that the location of intermediate producer services exerts an important influence on the location of manufacturing.

First, the theoretical literature, which stretches back as far as Marshall (1890), clearly deduces that buyers and sellers of intermediates will co-locate to minimize their costs. This is the essence of the well-known vertical linkages model of the New Economic Geography (Puga, 1999; Venables, 1996).

Second, the empirical literature also corroborates that intermediate producer services and manufacturing tend to locate near each other. In this context Andersson (2004) deduces that, in Swedish urban areas, the size of the manufacturing sector can be explained by the size of the service sector and vice versa, defining clusters of industrial and knowledge-intensive service firms. His results suggest that the location of manufacturing employment can be explained by its accessibility to intermediate producer services. Holl (2004) analyzes the case of Portuguese manufacturing companies and deduces, among other conclusions, that firms that change their location show a strong preference for areas that are well endowed in intermediate producer services. Taking data from Belgian urban areas between 1982 and 1996, Moyart (2005) confirms that being specialized in services, especially in intermediate producer services, increases the attractiveness of a zone to manufacturing companies. Chen and Chen (2011), using data from 69 cities and regions in the Chinese province of Zhejiang, deduce that services' location has a clear impact on manufacturing's location, although different behaviors appear depending on the size of the city. Panel data from 286 Chinese cities in the period 2003–2008 are used by Ke et al. (2014) to conclude that manufacturing firms tend to locate where intermediate producer services are already located and vice versa, in such a way that a cumulative process of co-agglomeration of the two sectors in specific areas is found.

From the literature reviewed in the previous paragraph, we can conclude that there are strong complementarities between the secondary and the tertiary sector that, without doubt, simultaneously influence the location of both.[2] Therefore, we can refer to the stylized fact that co-location exists between some types of services and manufacturing, at least to a certain extent.[3]

Finally, we carry out a very simple empirical exercise to illustrate, with recent data, that services do matter for industrial concentration. We take information from the US Bureau of Labor Statistics for the year 2014 at the US county level, specifically the location quotients (LQ_{mi}) of the 21 three-digit North American Industry Classification System (NAICS) manufacturing sectors (the codes numbered between 311 and 339)[4] and the location quotients (LQ_{sj}) of a very representative intermediate producer service, management of companies and enterprises (code 551). An OLS regression, $LQ_{sj}=a_0+a_1LQ_{mi}$, is estimated for all the possible cases, in which a_1 is the relevant parameter. If positive, it indicates that counties where a manufacturing sector is overrepresented are accompanied by an intermediate producer service sector that is also overrepresented and, therefore, favors the evidence of co-location.

The results of the 21 regressions are as follows. At the 5% level of significance, a_1 is significant and positive in the following cases: printing and related support

[2] There is great variability between manufacturing sectors with respect to the share of business services in their total output (see Table 2 in Guerrieri and Meliciani, 2005). We can also find very intense intercountry variability in these shares (see Figure 1 in Francois and Woerz, 2008).

[3] Interdependence between intermediate producer services and manufacturing is the leitmotiv of our paper. The general interdependence between all the sectors in the economy is empirically highlighted by Arbia et al. (2012) and Saari et al. (2014). Our model is a particular case of these general linkages.

[4] The manufacturing industries are the following: food manufacturing (mnfg), beverage and tobacco products mnfg, textile mills, textile product mills, apparel mnfg, leather and allied product mnfg, wood product mnfg, paper mnfg, printing and related support activities, petroleum and coal product mnfg, chemical mnfg, plastic and rubber product mnfg, nonmetallic mineral product mnfg, primary metal mnfg, fabricated metal product mnfg, machinery mnfg, computer and electronic product mnfg, electrical equipment and appliance mnfg, transportation equipment mnfg, furniture and related product mnfg and miscellaneous mnfg.

activities, computer and electronic products, miscellaneous and chemical and electrical equipment and appliances. It is negative and significant for wood products. From this very simple empirical analysis, we can extract two main outcomes. First, the dominant correlation between the LQs of manufacturing and intermediate producer services is positive, which confirms the hypothesis of co-location. Second, depending on which pair of intermediate producer services and manufacturing sector is considered, the relationship is of one of two types. The theoretical model that we propose can help to explain the second outcome. We will see later that, for example, a less efficient production service sector tends to make the concentration of manufacturing more difficult; this might be the case of the intermediate producer services for wood products. The positive relationships between services and manufacturing (estimated a_1 greater than zero and significant at 5%) might be explained by a very efficient service sector. These explanations would require specific research in any case. We fully agree with Shearmur and Doloreux (2008) that "the causation underlying the correlation between KIBS growth and manufacturing calls for further study." In this paper we try to fill this gap from a theoretical perspective.

3. THE MODEL

The basic structure of the model is built on the analytically solvable model developed by Forslid and Ottaviano (2003) with the new incorporation of an intermediate producer service sector.[5] The economy is composed of two regions (1 and 2) and two final consumer goods (X: manufactured goods; A: agricultural goods or food). There are three factors of production, two primary (L: unskilled labor; H: skilled labor) and one intermediate (S: intermediate producer services). Obviously, $L_1+L_2=L$ and $H_1+H_2=H$; each of these workers inelastically supplies one unit of his or her type of labor. For the sake of simplicity, and because this supposition does not affect the qualitative results, we consider unskilled workers to be equally distributed between regions, $L_i=L/2$.

[5] See Pan (2014) for an alternative framework for adding a producer service sector to a theoretical model; see also Kranich (2009) for an analytically solvable version of Krugman's original model.

Most of the literature on immigration considers that the level of education is an important variable to explain migration decisions. Specifically, it shows that there is a direct correlation between workers' level of qualification and their international mobility (Antolin and Bover, 1997; Chiquiar and Hanson, 2005; Chiswick, 1999; Docquier et al., 2007). As in the original model of FO, it follows from this that unskilled labor is only mobile between sectors, while skilled labor is mobile between sectors and regions. Therefore, the latter can be understood to be self-employed entrepreneurs who move freely between countries, hence the name of this model in the literature: the Footloose Entrepreneur Model (FE).

3.1. Demand

Consumer demand

The Cobb–Douglas preferences of a representative consumer from region i are defined over two goods: X_i (manufacturing) is horizontally differentiated and tradable; and A_i (agriculture) is homogeneous and freely traded. In short, the utility function is given by:

$$U_i = X_i^{\mu} A_i^{1-\mu} \tag{1}$$

where $\mu \in (0,1)$ is a constant.

Manufacturing is a differentiated good defined according to the following CES-type aggregate, where $\sigma>1$ is the elasticity of the demand for any variety and the elasticity of substitution between any two varieties.

$$X_i = \left(\int_{n \in N^x} d_i(n)^{\frac{\sigma-1}{\sigma}} dn \right)^{\frac{\sigma}{\sigma-1}} \tag{2}$$

where $d_i(n)$ is the manufacturer's consumption of the n-th variety and N^x is the total number of varieties ($N^x = N_1^x + N_2^x$, with obvious notation). From the maximization problem of (1), the demand from residents in location i for a manufactured variety produced in j is:

$$d_{ji}(n) = \frac{p_{ji}(n)^{-\sigma}}{P_{Ni}^{1-\sigma}} \mu Y_i \qquad i, j = \{1,2\} \tag{3}$$

where p_{ji} is the consumption price of a variety produced in j and sold in i and P_{Ni} is the local price index in region i, CES type, associated with expression (2):

$$P_{Ni} = \left[\int_{n \in N^x_i} p_{ii}(n)^{1-\sigma} dn + \int_{n \in N_j^x} p_{ji}(n)^{1-\sigma} dn \right]^{1/1-\sigma} \quad (4)$$

In turn, the local income in i, Y_i, is determined by the sum of the real-wage (hereafter, we always refer to real wages) rents of the primary inputs: $Y_i = W_i H_i + W_i^L L_i$, where W_i (W_i^L) is the wage of the skilled workers (unskilled workers).

Manufacturing firm demand for intermediate producer services

Before describing the supply side, it should be taken into account that, apart from the final consumption of each consumer, given the vertical linkages between firms, we have to consider that manufacturing firms demand intermediate producer services. As will be seen in the total cost functions of the manufacturing companies, services act as a fixed input (equation (10)). Specifically, to produce X(n) units of variety n, a manufacturing company incurs fixed costs[6] from the employment of γ units of services. We understand that these are costs that industrial companies have to bear, regardless of the level of production that they bring to the market. In short, these are typical intermediate producer services, like those associated with consultants of different kinds: legal services, specialist logistics services, financial services, economic services, advertising costs, costs related to the design and marketing of industrial products, industrial engineering, technological transfer services, maintenance services and research services.

The service sector is defined according to the following CES-type aggregate:

$$\gamma = \left(\int_{r \in N_i^r} d_i(r)^{\frac{\rho-1}{\rho}} dr \right)^{\frac{\rho}{\rho-1}} \qquad i = \{1,2\} \quad (5)$$

where $\rho > 1$ is the elasticity of the demand for any variety and the elasticity of substitution between any two varieties, $d_i(r)$ is the consumption of the r-th variety produced in region i and N^r_i is the total number of varieties in that region. Since the amount of services needed is fixed by definition, the manufacturing firm only has to minimize the monetary cost of obtaining γ units of services, Min

[6] See García-Pires (2013) for an NEG model in which manufacturing firms also have fixed costs.

$\int_{r \in N_i^r} p_i(r) d_i(r) dr$ subject to (5), where $p_i(r)$ is the consumption price of the r-th variety in the i-th region.

This yields the following expression, which is slightly different from its manufacturing equivalent (3); see Fujita et al. (1999), equation (4.8), for details:

$$d_i(r) = \frac{p_i(r)^{-\rho}\gamma}{P_{Ri}{}^{-\rho}} \tag{6}$$

where P_{Ri} is the local price index, CES type, associated with expression (5); notice that, since services are non-tradable, the price index is now region-specific:

$$P_{Ri} = \left[\int_{r \in N_i^r} p_i(r)^{1-\rho} dr \right]^{1/(1-\rho)} \tag{7}$$

3.2. Supply

Turning to the supply side, the firms in agricultural sector A produce under constant returns to scale and perfect competition and employ unskilled labor as the only productive factor. Without loss of generality, we suppose that one unit of output requires one unit of labor. At the same time, as mentioned above, it is a homogeneous good that is freely traded between regions and that we take as a numeraire. All the above allows us to conclude that $P_i^A = W_i^L = 1$, where P_i^A is the price of the agricultural good in the i-th region (i=1, 2).[7]

Firms in the service sector produce horizontally differentiated services that are used as inputs by the industrial sector. It is important to characterize the type of vertical linkage between these companies (services and manufacturing) in detail. First, we need to define whether the services' intermediate input is tradable. Indeed, some services to firms, thanks to recent improvements in telecommunications and in information and communication technology (ICT) in general, can take place between a user and a producer in different countries if, for example, all that is required is an email or a phone call to make contact and provide the service. However, this is not always the case, and trading the

[7] Unskilled labor is mobile between sectors, so wage equalization holds as long as the agricultural good is produced in both regions. For this, we introduce the non-full-specialization condition (Baldwin et al., 2003, p. 72), which establishes that the overall consumption of the agricultural good in the economy is greater than the maximum production that can be achieved if the sector is concentrated in only one of the regions.

service requires cross-border movements by the service producers, the consumers or both. Thus, the costs associated with the consumption of the service (including time costs) are very high in situations in which the two parties involved need to hold very frequent meetings, in the same language and knowing the same codes; in this case, the service sector companies must be located in the same region as the services are consumed. In this model we consider the latter case, so that intermediate services are incorporated into the production processes of the manufacturing companies of the region where they are produced and, consequently, are non-tradable.[8]

Second, due to their special characteristics, services use skilled labor as their only production factor, examples being highly qualified people (economists, engineers, lawyers, advertising and marketing experts, actuaries, insurance brokers). There is a vast literature that considers that producer or business services are knowledge-intensive (see, for example, the survey on knowledge-intensive business services of Muller and Doloreux, 2009).

The productive process of these companies is carried out with increasing returns to scale and monopolistic competition (services are differentiated horizontally) with free entry. Specifically, a service firm incurs a requirement of λS_i units of skilled labor to produce S_i units of output services. In this way a typical service company producing variety r maximizes the following profit function:

$$\pi_i(r) = p_i(r)S_i(r) - \lambda W_i S_i(r) - B \tag{8}$$

where S_i is the level of output of the service company in question and B is a fixed monetary cost in units of the numeraire good. The first-order condition for profit maximization gives the price of services as a mark-up on the wages of the skilled workers:

$$p_i(r) = p_i = \lambda\left(\frac{\rho}{\rho - 1}\right)W_i \tag{9}$$

where p_i denotes the price of services in region i.

[8] Related to this first characteristic, Francois and Woerz (2008) find that, while manufacturers dominate direct trade data, services are often the most important activities contributing to final export flows, given the importance of non-traded service inputs in the production of traded goods.

Finally, firms in manufacturing sector X produce under monopolistic competition and increasing returns to scale, using both skilled and unskilled labor and services. Specifically, to produce $X_i(n)$ units of variety n, a company incurs βX_i units of marginal costs associated with unskilled labor and fixed costs involving the employment of α units of skilled labor[9] and γ units of services. Now, a vertical link is introduced into the equation of total costs so that services are a fixed cost for manufacturing firms. Thus, the total cost equation is given by the following expression:

$$TC_i(n) = \beta W_i^L X_i(n) + \alpha W_i + \gamma p_i \tag{10}$$

In equilibrium skilled labor market clearing implies that the total number of manufacturing firms in region i is determined by:

$$N_i^x = \frac{\varepsilon_i H_i}{\alpha} \tag{11}$$

where ε_i ($(1-\varepsilon_i)$) is the percentage, on a per-unit basis, of the skilled labor in region i dedicated to producing manufactured goods (intermediate producer services).[10] The number of manufacturing companies in a region is equal to the amount of skilled workers who move to that sector ($\varepsilon_i H_i$) divided by the fixed magnitude of skilled labor that each manufacturing company needs to start production (α).

As in the case of agricultural goods, manufactured goods are traded between regions, but, unlike the former, they are subject to an iceberg-type transport cost in such a way that, for one unit of manufactured goods to reach the other region, $\tau>1$ units must be shipped. Obviously, if $\tau=1$, there are no transport costs or, to put it another way, there are no barriers to trade.

According to the above, a manufacturing company in region i maximizes the following profit equation:

$$\pi_i(n) = p_{ii}(n)d_{ii}(n) + p_{ij}(n)d_{ij}(n) - \beta\lfloor d_{ii}(n) + \tau d_{ij}(n)\rfloor - \alpha W_i - \gamma p_i \tag{12}$$

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9 In this model it is assumed that the productivity of skilled labor is constant. In the real world this productivity is affected by the education level or the years of experience. This possibility defines an interesting extension of the model.

10 The analytical tractability of the model is maintained as long as ε_i is treated exogenously. We are conscious that ε_i is endogenous in essence and that this share might be affected by the wage differential across regions, by the mass of firms in service and manufacturing activities in each region and by trade openness. However, although the comparative static effects deduced in Section 4 could, at least to a certain extent, be conditioned by this assumption about the exogeneity of this parameter, the reasonability and plausibility of these effects lead us to think that they are robust to different hypotheses regarding ε_i, i=1,2.

where it has already been taken into account that the wage of the unskilled workers is the unit and $\tau d_{ij}(n)$ represents the total supply to location j, which includes the fraction of output lost due to transport costs. Consequently, maximizing (12) gives us:

$$p_{ii}(n) = \frac{\beta\sigma}{\sigma - 1} \qquad p_{ij}(n) = \frac{\tau\beta\sigma}{\sigma - 1} \tag{13}$$

for each i and j. Thus, as in the original model, the equilibrium prices are equalized across regions and independent of the agents' localization decisions. Introducing (13) into the price index, we obtain:

$$P_{Ni} = \frac{\beta\sigma}{\sigma - 1}\left[N_i^x + \phi N_j^x\right]^{\frac{1}{1-\sigma}} \tag{14}$$

where $\phi = \tau^{1-\sigma}$ is the freeness of trade parameter, which takes values between zero and one; the bigger it is, the freer trade is.

Due to the free entry and exit of firms in the manufacturing sector, no company obtains a strictly positive profit, meaning that their scale of production is such that the operating profits equal the fixed costs, that is to say, skilled labor and services:

$$\alpha W_i + \gamma p_i = p_{ii}(n)d_{ii}(n) + p_{ij}(n)d_{ij}(n) - \beta\left(d_{ii}(n) + \tau d_{ij}(n)\right) \tag{15}$$

so that, substituting (9) and (13), the wage per skilled worker is:

$$W_i = \frac{(\rho - 1)\beta X_i}{\left[\rho(1 + \frac{\gamma\lambda}{\alpha}) - 1\right]\alpha(\sigma - 1)} \tag{16}$$

where $X_i = d_{ii}(n) + \tau d_{ij}(n)$ is the total production of a firm located in i. Expression (16), together with (3), (13) and (14), allows us to obtain the output of a typical company in region i:

$$X_i = \frac{\sigma - 1}{\beta\sigma}\left(\frac{\mu Y_i}{N_i^x + \phi N_j^x} + \frac{\phi\mu Y_j}{\phi N_i^x + N_j^x}\right) \tag{17}$$

Using (17) and (11), the wages of a skilled worker, equation (16), can be written as:

$$W_i = \frac{\rho - 1}{\left(1 + \frac{\gamma\lambda}{\alpha}\right)\rho - 1}\frac{\mu}{\sigma}\left(\frac{Y_i}{\varepsilon_i H_i + \phi\varepsilon_j H_j} + \frac{\phi Y_j}{\phi\varepsilon_i H_i + \varepsilon_j H_j}\right) \tag{18}$$

In turn, local income is given by:

$$Y_i = W_i H_i + L/2 \tag{19}$$

For i=1,2 the system consisting of equations (11), (13), (16), (17) and (19) determines the endogenous variables N^x_i, P_{Ni}, W_i, X_i and Y_i for a given allocation of skilled workers H between the regions and the sectors ($\varepsilon_i,\varepsilon_j$). To find the spatial equilibrium, we need to calculate the ratio between the skilled workers' wages in each region. In Appendix A and defining $h=(H_1/H)$ as the percentage of skilled workers in region 1, we show that:

$$\frac{W_1}{W_2} = \frac{2\phi\varepsilon_1 h + (1-h)\left(\left(\varepsilon_2 - \frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1}\frac{\mu}{\sigma}\right) + \left(\varepsilon_2 + \frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1}\frac{\mu}{\sigma}\right)\phi^2\right)}{2\phi\varepsilon_2(1-h) + h\left(\left(\varepsilon_1 - \frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1}\frac{\mu}{\sigma}\right) + \left(\varepsilon_1 + \frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1}\frac{\mu}{\sigma}\right)\phi^2\right)} \tag{20}$$

Based on this equation, equilibrium is reached when $(d(W_1/W_2)/dh)=0$ so that, when skilled laborers move between regions, the relative wage does not change and, thus, there is no incentive for such movement. This condition is fulfilled for the following value of the freeness of trade parameter:

$$\phi_W = \sqrt{\frac{\left(\varepsilon_1 - \frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1}\frac{\mu}{\sigma}\right)\left(\varepsilon_2 - \frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1}\frac{\mu}{\sigma}\right)}{\left(\varepsilon_1 + \frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1}\frac{\mu}{\sigma}\right)\left(\varepsilon_2 + \frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1}\frac{\mu}{\sigma}\right)}} \tag{21}$$

where $\phi_w \in (0,1)$ is a threshold for parameter ϕ and defines the interval in which dispersion ($\phi<\phi_w$) or concentration ($\phi>\phi_w$) dominates. Specifically, in the latter case, $\phi>\phi_w$ or, to put it another way, $(d(W_1/W_2)/dh)>0$: a process of accumulation of skilled workers in region 1 is taking place. In fact, our model is reduced to FO (in this paper we respect the original notation of FO as far as possible to facilitate the comparability between the two models) whenever the new parameters associated with the service sector adopt the following values: $\lambda=0$, $\gamma=0$ and $\varepsilon_i=1$.

It will be straightforward to verify that the freeness parameter condition of FO is a special case of our extension when there are no vertical linkages between sectors, specifically when the economy is only composed of the manufacturing and agricultural sectors. Thus, the three effects of the NEG models are still working in our model. The first two are centripetal forces: the market access effect (the tendency of monopolistic firms to locate in big markets) and the cost-of-living effect (locations with a large industrial sector have a lower price index of manufacturing). The third effect is a centrifugal force: the market-crowding effect (non-competitive firms tend to locate in regions with few competitors).

However, it is more interesting to examine the new elements arising from the introduction of the service sector into the model. To do so, for the value of ϕ_W always to be positive (and between zero and one), we need to impose the following restriction[11]:

$$\varepsilon_i > \left(\frac{\rho - 1}{\left(1 + \frac{\gamma\lambda}{\alpha}\right)\rho - 1} \right) \frac{\mu}{\sigma} = M \qquad i = \{1,2\} \tag{22}$$

M is between zero and one. This condition defines the minimum threshold for the percentage of skilled labor in the manufacturing sector in both regions. As can be observed in the last expression, this threshold depends as much on the parameters of manufacturing as it does on others associated with the service sector.

The intuition associated with equation (22) is obtained from the detailed analysis of (21) in the next section. It can be confirmed that the signs of (dM/dz), where $z=(\mu, \sigma, \rho, \lambda, \gamma, \alpha)$, are the opposites of ($d\phi_W$/dz), these derivatives being the basis for defining and commenting on the fundamental effects in Section 4.

4. COMPARATIVE STATIC EFFECTS

Before the analysis of the equilibrium and its stability, we carry out a simple comparative static analysis based on (21). Specifically, the sign of the derivative of ϕ_W is evaluated in relation to each of the relevant parameters. Thus, as reasoned above, if the derivative is positive (negative), an increase in the

[11] A more detailed analysis of (21) shows that the model can also work if ε_i<M, i=1, 2. However, this condition, while making sense mathematically, does not do so economically and, therefore, is not considered. First, the fulfillment of the restriction is compatible with a null ε_i. Second, it leads to the direction of the influences of the parameters σ and μ being the opposite to what is established and reasoned by all the previous literature, which makes no sense.

parameter in question increases (decreases) the value of ϕ_W without overrunning the interval (0, 1), favoring dispersion (concentration). This digression of the dispersion and agglomeration forces is useful because it supports the economic intuition associated with the relevant parameters of (21), characteristic of the manufacturing and service sectors.

Although we focus the analysis on the parameters of the service sector, we begin with the analysis of the parameters associated with the manufacturing sector (proof: see equations B.4 and B.5 in the Appendix).

$$\frac{d\phi_W}{d\mu} < 0 \qquad \frac{d\phi_W}{d\sigma} > 0 \tag{23}$$

It is observed that a greater percentage of expenditure in manufacturing (μ) reduces ϕ_W, and, thus, acts as a centripetal force.[12] At the same time, a greater elasticity of substitution between varieties of manufactured goods (σ) increases ϕ_W, favoring dispersion (if σ is infinite, the product is homogeneous). Both effects are completely standard within the NEG and have been well known since the seminal work of Krugman (1991).

The parameters that refer to services are novel. We refer to the first effect as the "service demand elasticity effect" (proof: see equation B.6 in the Appendix).

$$\frac{d\phi_W}{d\rho} < 0 \tag{24}$$

A service sector with little differentiation, close to perfect competition, with very elastic demands for each variety of the services (high ρ), reduces ϕ_W and, thus, favors concentration, behaving as a centripetal force. The economic explanation for the above is as follows. When the elasticity of demand and substitution among the different varieties of services is high, the demand of manufacturing firms for these products is very price sensitive, bringing down the price of services more than in a situation with more rigid demands. Given the operating profits in the industrial sector, which must be compensated for exactly by the payments associated with the two fixed costs, the relative cheapening of one of them (intermediate producer services) permits an increase in the part of the profits of the other (the skilled workers); in short, now and in the following,

[12] When we discuss centripetal and centrifugal forces, we always refer to the manufacturing sector. The main goal of this document is to determine whether services are a force of one or the other type for manufacturing.

higher payments for skilled labor in the industrial sector act as a force that encourages concentration.

It can be observed that the two equivalent parameters, σ and ρ, one for manufacturing and the other for services, influence the spatial equilibrium configuration of the industrial sector differently. In general, focusing on final manufactured goods (see Leite et al., 2013), the lower the elasticity of substitution between varieties, the greater the probability of industrial concentration. Consequently, it is very informative that our parameter ρ, which is associated with services that are intermediate inputs for manufacturing, has the opposite influence.

We call the second effect the “service production efficiency effect.” This effect is related to two parameters, one associated with services and the other with the link between manufacturing and services (proof: see equations B.7 and B.8 in the Appendix).

$$\frac{d\phi_w}{d\lambda} > 0 \qquad\qquad \frac{d\phi_w}{d\gamma} > 0 \tag{25}$$

The more efficient the service sector is in production (low λ for the production of services per se and low γ for the fixed amount of services needed for manufacturing), the smaller ϕ_w is, which favors the concentration of manufacturing; furthermore, like all of the above, it is a reasonable result. In terms of costs and profits, the explanation is similar to that of the previous effect. The more productive the service sector (lower fixed service requirements for manufacturing), the lower its associated costs for a typical manufacturing company, which, given the operating profits, frees up more funds for paying the other fixed factor, the skilled workers (see (15)). Thus, in this case of very efficient services in production, we have behavior typical of a centripetal force.

Third, there is what we call the “mobility of skilled workers effect” (proof: see equation B.9 in the Appendix).

$$\frac{d\phi_w}{d\alpha} < 0 \tag{26}$$

The higher the value of α, the more the concentration of manufacturing is favored. The explanation is twofold. On the one hand, this of course means a direct increase in revenue, αW, which manufacturing companies allocate to paying their fixed-factor skilled workers. On the other hand, more importantly, this result relates to a classic conclusion of NEG models, dating back to the pioneering model of Krugman (1991): the greater the importance of the mobile factor (greater α), in this case skilled workers, the more probable concentration is.

The relationship established between the supply-side parameters (α, γ and λ) and the industrial landscape is also logical from an economic point of view and is backed up by data from specific sectors. Let us examine this in more detail. A highly productive service sector (low γ and λ) favors concentration. To close the argument, we need to examine the relationship between the productivity of a sector and its employment level. In theory, there is a direct correlation between productivity and salary (a standard result in basic microeconomics is that, in perfect competition, the price of the product multiplied by the marginal input productivity equals the salary earned by the workers), and a higher salary attracts more employment to the sector. From an empirical point of view, there is also a positive relationship between employment growth and productivity in a sector (Manyika et al., 2011; Nordhaus, 2005). For illustration purposes only, Fernández de Guevara (2011), analyzing the Spanish economy with a disaggregation level dividing it into 29 sectors, finds that the "transport and communications" service sector is fifth in terms of productivity and fourth in terms of the number of employees in 2008. In short, a service sector that is very efficient in production is a mechanism that favors the concentration of manufacturing.

The results of all the previous paragraphs tend to reinforce Jansson's (2006) idea that the growth of the service sector and the gradual tertiarization of modern economies have had a greater impact on the intermediate service component than on the final consumption service component. This is an important stylized fact. At the same time, all the above is also connected to the fragmentation theory of Jones and Kierzkowski (1990, 2001); effectively, while using different approaches, both works emphasize, in a dynamic and international context, the role of intermediate services in manufacturing in the geographical fragmentation of production; these service links are assumed to exhibit the kind of increasing returns associated with fixed costs that, as in our theoretical model, are invariant to the scales of the industrial output.

5. EQUILIBRIUM AND STABILITY

This section attempts to determine the region in which the skilled workers are located and to analyze the stability of these spatial configurations. To determine the location, we assume that individuals move to the place that offers the highest current utility and that they are short-sighted. To see whether the symmetric equilibrium is stable or not and to establish the bifurcation diagram, we need to apply the two local stability tests that the NEG literature usually utilizes.

Accordingly, we assume that skilled workers follow a Marshallian adjustment process:

$$\dot{h} = {dh}/{dt} = \begin{cases} W(h,\phi) & if \quad 0 < h < 1 \\ \min\left[0, W(h,\phi)\right] & if \quad h = 1 \\ \max\left[0, W(h,\phi)\right] & if \quad h = 0 \end{cases} \tag{27}$$

where t is time, which is left implicit to simplify the notation, and W(h,ϕ) is the difference between the indirect utility functions of the two regions:

$$W(h,\phi) \equiv \eta\left(\frac{W_1}{P_{N1}^{\mu}} - \frac{W_2}{P_{N2}^{\mu}}\right) \tag{28}$$

where $\eta=\mu^{\mu}(1-\mu)^{1-\mu}$. Using equations (11) and (14), we obtain the two price indices:

$$P_{N1} = \frac{\beta\sigma}{\sigma-1}\left[\frac{H}{\alpha}\right]^{1/1-\sigma}\left[\varepsilon_1 h + \phi\varepsilon_2(1-h)\right]^{1/1-\sigma} \tag{29}$$

$$P_{N2} = \frac{\beta\sigma}{\sigma-1}\left[\frac{H}{\alpha}\right]^{1/1-\sigma}\left[\phi\varepsilon_1 h + \varepsilon_2(1-h)\right]^{1/1-\sigma} \tag{30}$$

Substituting (20), (29) and (30) in (28), we obtain the following expression for W(h,ϕ):

$$W(h,\phi) = \frac{\Phi}{\substack{\phi\left[\varepsilon_i h^2(\varepsilon_i - M) + \varepsilon_j(1-h)^2(\varepsilon_j - M)\right] \\ +h(1-h)\left[\varepsilon_i\varepsilon_j - M(\varepsilon_i+\varepsilon_j) + M^2 + \phi^2(\varepsilon_i\varepsilon_j - M) + \phi^2 M(1-M)\right]}} xV(h,\phi) \tag{31}$$

where M is the threshold condition obtained in (22),

$$\Phi = \eta(\rho-1)\mu L(\sigma-1)^{\mu}(\alpha)^{\mu/1-\sigma} \Big/ 2\sigma\left(\left(\frac{\gamma\lambda}{\alpha}+1\right)\rho-1\right)(\beta\sigma)^{\mu}(H)^{1+2\mu-\sigma/1-\sigma}$$

Φ being a positive bundling parameter and

$$V(h,\phi) = \frac{2\phi\varepsilon_1 h+(1-h)\left(\varepsilon_2-M+(\varepsilon_2+M)\phi^2\right)}{\left[\varepsilon_1 h+\phi\varepsilon_2(1-h)\right]^{\mu/1-\sigma}} - \frac{2\phi\varepsilon_2(1-h)+h\left(\varepsilon_1-M+(\varepsilon_1+M)\phi^2\right)}{\left[\varepsilon_2(1-h)+\phi\varepsilon_1 h\right]^{\mu/1-\sigma}} \tag{32}$$

Equilibrium is obtained when $\dot{h}=0$; in this case, the skilled workers have no incentive to move from one region to another. As long as W(h,ϕ) is positive, the workers will move from region 2 to region 1, and the situation will be the other way around if it is negative. An inspection of (31) allows us to deduce that, in the last instance, all that matters is V(h,ϕ). In essence, the discussion and the intuition associated with the stability of the equilibrium are the same as in Fujita et al. (1999) and Krugman (1991). In both models w_i, i=1,2 denote the real wage in region i and $\xi \in [0,1]$ represent the share of the manufacturing sector in region 1 (see Figure 1). The workers move to the region with a higher real wage.

[Insert Figure 1 Here]

The symmetric landscape (ξ=0.5) is always an equilibrium ($w_1=w_2$ and the industrial workers have no incentive to move). If (w_1-w_2) is greater (smaller) than 0, the workers want to move to region 1(2), as the arrows in Figure 1 show. Therefore, total concentration is stable if and only if (w_1-w_2)<0 in ξ=0 and (w_1-w_2)>0 in ξ=1. Replace (w_1-w_2) with V(h,ϕ) and ξ with h in our model and the basic reasoning (mutatis mutandis) about the stability of the equilibrium is equivalent. The symmetric equilibrium, h=1/2, is stable if the slope of V(h,ϕ) is not positive at h=1/2.

To sum up, solving the model when the industry is agglomerated in one of the regions shows that the equilibrium is only sustainable for trade freeness above the so-called sustain point. This level of trade freeness will be obtained by h=1 or h=0 in (32). Conversely, regarding internal equilibria, we can prove that V(h,ϕ)=0 is verified at least three times for 0<h<1. We can also verify that one of these times corresponds to the symmetrical equilibrium h=1/2. For this to be stable, it must be true that $V_h(1/2,\phi)<0$, where the sub-index denotes the partial derivative of V in relation to the variable in question. This value of trade freeness is the so-called break point and is obtained by evaluating the derivative of (32) with respect to h at h=1/2.

To continue with the stability analysis, we need to distinguish two cases, which differ regarding whether the distribution of skilled workers between the manufacturing sector and the service sector is the same or not in the two regions.

5.1. Case 1

The simplest scenario is $\varepsilon_1=\varepsilon_2=\varepsilon$. In this particular case, $V(0,\phi)= -V(1,\phi)$, so that, for the corner equilibria to be stable, the following must be fulfilled:

$$\varepsilon - M + (\varepsilon + M)\phi_s^2 - 2\phi_s^{\frac{1-\sigma-\mu}{1-\sigma}}\varepsilon^{\frac{1-\sigma-2\mu}{1-\sigma}} = 0 \qquad (33)$$

where ϕ_s is the sustain point.

The dispersion of industry is stable if the transport costs are high enough for ϕ to be lower than the break point, ϕ_b, which is defined as:

$$\phi_b \equiv \phi_w \frac{1 - 1/\sigma - \mu/\sigma}{1 - 1/\sigma + \mu/\sigma} \qquad (34)$$

As is well known, starting from (30), it can be proven that ϕ_b increases with σ and decreases with μ. Now, though, in our model there are also characteristics of the service sector that affect the magnitude of the break point by means of ϕ_w. As expected in light of what we have already seen, the larger ρ (service demand elasticity effect) and α (mobility of skilled workers effect) and the smaller λ and γ (service production efficiency effect) are, the lower the value of ϕ_b will be and the greater the total concentration of manufacturing.

Meanwhile, as in the original core–periphery model, the so-called “no black-hole condition” exists. This establishes that, for the model to make sense and not always generate an equilibrium of total concentration, regardless of the values of the parameters, $\mu<\sigma-1$ must be fulfilled. Note that this condition is identical to that considered by FO, so it is also less restrictive than the one assumed in the traditional core–periphery model.

To summarize, all the possible equilibria are represented in the bifurcation diagram shown in Figure 2,[13] in which the stable equilibria are depicted with a continuous thick line and the unstable equilibria with a broken thick line.

[Insert Figure 2 Here]

Figure 3 synthesizes the effects of the key parameters of the service sector on the results of dispersion or concentration of the spatial equilibria. On the left-hand side, a reduction in λ or in γ (a very productive service sector), an increase in α (fixed skilled labor for manufacturing) and an increase in ρ (high elasticity of demand and substitution between varieties of services) will lower both the sustain point and the break point, acting as centripetal forces. The opposite happens on the right-hand side of the figure.

[Insert Figure 3 Here]

5.2. Case 2

Now the distribution of skilled workers between sectors can differ in the two regions: $\varepsilon_1 \neq \varepsilon_2$. Analyzing equation (32), in this case we obtain two different sustain points depending on whether the total concentration occurs in one region or another:

$$h = 0 \quad \varepsilon_2 - M + (\varepsilon_2 + M)\phi_{s2}^2 - 2\phi_{s2}^{\frac{1-\sigma-\mu}{1-\sigma}} \varepsilon_2^{\frac{1-\sigma-2\mu}{1-\sigma}} = 0 \tag{35}$$

$$h = 1 \quad 2\phi_{s1}^{\frac{1-\sigma-\mu}{1-\sigma}} \varepsilon_1^{\frac{1-\sigma-2\mu}{1-\sigma}} - \varepsilon_1 + M - (\varepsilon_1 + M)\phi_{s1}^2 = 0 \tag{36}$$

The sustain point of one region will be higher than that of the other if it uses a greater percentage of skilled labor in producing manufactured goods. That is, for the equilibrium with total concentration to be stable in a region that dedicates a high percentage of its skilled labor to the manufacturing sector, the transport costs of goods between the regions must be close to free trade.

Additionally, to obtain the break point, we must give concrete values to ε_1 and ε_2:

[13] The bifurcation pattern that emerges at the break point is obtained by a standard analysis of the function W(h,Φ), because the internal equilibrium is verified at least three times for 0<h<1 (see Guckenheimer and Holmes, 1990). They show that the corresponding bifurcation is a tomahawk that is now affected by the characteristics of the service sector.

$$V_h(h,\phi)=\frac{\left[(2\phi\varepsilon_1-\Omega)\left(\frac{1}{2}\varepsilon_1+\frac{1}{2}\phi\varepsilon_2\right)-\left(\phi\varepsilon_1+\frac{1}{2}\Omega\right)\frac{\mu}{1-\sigma}(\varepsilon_1-\phi\varepsilon_2)\right]}{\left[\frac{1}{2}\varepsilon_1+\frac{1}{2}\phi\varepsilon_2\right]^{\mu/1-\sigma}}-\frac{\left[(-2\phi\varepsilon_2+\Psi)\left(\frac{1}{2}\varepsilon_2+\frac{1}{2}\phi\varepsilon_1\right)-\left(\phi\varepsilon_2+\frac{1}{2}\Psi\right)\frac{\mu}{1-\sigma}(\phi\varepsilon_1-\varepsilon_2)\right]}{\left[\frac{1}{2}\varepsilon_2+\frac{1}{2}\phi\varepsilon_1\right]^{\mu/1-\sigma}} \quad (37)$$

where

$$\Omega=\varepsilon_2-M+(\varepsilon_2+M)\phi^2 \quad (38)$$

$$\Psi=\varepsilon_1-M+(\varepsilon_1+M)\phi^2 \quad (39)$$

To reflect what happens with the number of equilibria and their stability, we present two extreme cases in Figure 4 and Figure 5. The values used to draw the diagrams are as follows: μ=0.3 and σ=4 (the same as in Krugman, 1991); on the service sector side, ρ=5, α=2, λ=0.25 and γ=4 are considered; in Figure 4 ε_1=0.9 and ε_2=0.75, while in Figure 5 ε_1=0.9 and ε_2=0.25. All the values comply with the restrictions imposed by the model (specifically the no-black-hole condition, the non-full-specialization condition and the threshold condition (22)).

[Insert Figure 4 Here]

[Insert Figure 5 Here]

We can comment briefly on the two figures. First, the stable equilibrium in h=1/2 disappears and, for high transport costs, there is dispersion but it is not symmetrical. Specifically, the region with the lowest ε accumulates the greatest percentage of industrial activity, which, as is logical, is much more accentuated in Figure 5 for the values of ε_i. As the trade barriers fall – that is, as we move from right to left – the skilled labor gradually migrates to region 2, which has a greater percentage of skilled labor dedicated to the service sector, until the break point is reached. A little beyond this point, total concentration is stable only in the region with the lowest ε. When the trade costs fall enough to be to the right of ϕ_{s1}, concentration is also possible in the other region.

In short, the two graphs are qualitatively similar, although Figure 5 shows the same characteristics with greater intensity. In any case, the region with the most skilled workers in services is the one with the most industry when there is asymmetrical dispersion and is the one that, for a greater range of values of the freeness of trade parameter, would accumulate all manufacturing if there were total concentration.

6. DISCUSSION AND CONCLUSIONS

The main aim of this paper is to analyze how the consideration of intermediate producer services, which are needed in the productive process of manufacturing, affects the location of the manufacturing industry. To achieve this aim, we need to begin with an NEG model, and we choose the Footloose Entrepreneur Model of Forslid and Ottaviano (2003). It is deemed to be the most appropriate for two reasons. On the one hand, it is flexible and easy to handle, with a wide range of final goods and inputs, without diminishing the operability of the model. On the other hand, it is the first core–periphery model that, unlike Krugman's (1991) original model, can be completely resolved with pen and paper, a desirable characteristic that is maintained in our extended and modified model.

The consensus that services are a key sector in present-day economics is pointed out in the introduction. This is not only because of the obvious evidence that they represent an important part of the GDP in developed countries but also because, as an intermediate input in many manufactured goods, they act as a catalyst for manufacturing, generating industrial gains in productivity and efficiency. To put it another way, intermediate producer services that present economies of scale can eventually transmit this characteristic to the corresponding manufacturer.

The framework in which we define our model consists of two final goods (agricultural goods, manufactured goods) and three inputs (two primary, skilled and unskilled labor, and one intermediate, producer services). The vertical linkage relationship established between services and manufacturing is especially important: manufactured goods are produced with unskilled labor, skilled labor and intermediate producer services. The intermediate producer services are differentiated, have increasing returns to scale, are non-tradable, need only skilled labor for their production and are a fixed cost for manufacturing production.

One of the interesting aspects of this study is that, thanks to the model's vertical linkage, the industrial characteristics that favor the location of industrial activity in a region become de facto service characteristics.

The first is the "service demand elasticity effect": a service sector that is not highly differentiated, with very elastic demands for each variety of the services, favors the concentration of industry. When the elasticity of demand and substitution among the different varieties of services is high, the demand of manufacturing companies for these products is very price-sensitive, bringing down the price of services. Given the operating profits in the industrial sector, which must be compensated exactly with the payments associated with the two fixed costs, the relative cheapening of one of them (intermediate producer services) permits an increase in the part of these profits that goes to the other (the skilled workers). In short, higher payments for skilled labor in the industrial sector act as a centripetal force.

The second is the "service production efficiency effect": the more efficient the production in the service sector (greater productivity for the production of services per se and lower requirements for a fixed amount of services for manufacturing), the more likely it is that manufacturing will be concentrated. In terms of costs and profits, the explanation is similar to the previous effect: a more productive service input and lower fixed service requirements for manufacturing lower the associated costs for a typical manufacturing company, which, given the operating profits, frees up more funds for paying the other fixed factor, the skilled workers.

The third is the "mobility of skilled workers effect": the manufacturing sector has two fixed factors, intermediate services and skilled workers. The former is immobile between regions and the latter is mobile. The more skilled workers are necessary for starting a manufacturing company, the more probable concentration becomes. This is a standard result in the models of the New Economic Geography: greater importance of the mobile factor favors a more concentrated economic landscape.

Finally, we want to end with a discussion. Beyond these three new effects, described in detail in the previous paragraphs and in Section 4, the main message of the paper could be stated as follows: because of the interindustry productive linkages between manufacturing firms and intermediate producer service firms, their location decisions cannot be understood as being independent. Moreover, they are tightly connected in modern economies, synergies and co-agglomeration economies existing between the two sectors that, eventually, generate geographical clusters. This is a stylized fact that is corroborated in several empirical works using data from different geographical areas (see Section 2).

Therefore, the debate about the convenience, for a city or region, of fostering either industry or services to promote growth is spurious. They are complements rather than substitutes and intermediate producer services need to be located near manufacturing plants and vice versa. In a nutshell, to be fully operative, the industry departments of regional and local governments should be complemented by a (intermediate producer) service counterpart.

APPENDIX A

Plugging (18) into (17), similarly to FO, we generate a two-equation system that enables us to obtain individual expressions for the wages depending on the number of skilled workers in each region:

$$W_i = \frac{\left(\frac{\rho-1}{\left(1+\gamma\lambda/\alpha\right)\rho-1}\right)\frac{\mu}{\sigma}\frac{L}{2}\left(2\phi\varepsilon_i H_i + H_j\left(\varepsilon_j - \left(\frac{\rho-1}{\left(1+\gamma\lambda/\alpha\right)\rho-1}\right)\frac{\mu}{\sigma} + \left(\varepsilon_j + \left(\frac{\rho-1}{\left(1+\gamma\lambda/\alpha\right)\rho-1}\right)\frac{\mu}{\sigma}\right)\phi^2\right)\right)}{\phi\left[\varepsilon_i H_i^2\left(\varepsilon_i - \left(\frac{\rho-1}{\left(1+\gamma\lambda/\alpha\right)\rho-1}\right)\frac{\mu}{\sigma}\right) + \varepsilon_j H_j^2\left(\varepsilon_j - \left(\frac{\rho-1}{\left(1+\gamma\lambda/\alpha\right)\rho-1}\right)\frac{\mu}{\sigma}\right)\right] + H_i H_j \Gamma} \tag{A.1}$$

where

$$\begin{aligned}\Gamma = {} & \varepsilon_i\varepsilon_j - \left(\frac{\rho-1}{\left(1+\gamma\lambda/\alpha\right)\rho-1}\right)\frac{\mu}{\sigma}\left(\varepsilon_i + \varepsilon_j\right) + \left(\frac{\rho-1}{\left(1+\gamma\lambda/\alpha\right)\rho-1}\right)^2\left(\frac{\mu}{\sigma}\right)^2 \\ & + \phi^2\left(\varepsilon_i\varepsilon_j - \left(\frac{\rho-1}{\left(1+\gamma\lambda/\alpha\right)\rho-1}\right)\frac{\mu}{\sigma}\right) + \phi^2\left(\frac{\rho-1}{\left(1+\gamma\lambda/\alpha\right)\rho-1}\right)\frac{\mu}{\sigma}\left(1 - \left(\frac{\rho-1}{\left(1+\gamma\lambda/\alpha\right)\rho-1}\right)\frac{\mu}{\sigma}\right)\end{aligned} \tag{A.2}$$

APPENDIX B

Before beginning with the derivatives of the threshold in relation to each of the relevant parameters, to simplify them, we use F, T and Ξ to denote the following expressions:

$$F = \left[\frac{(\varepsilon_1 - M)(\varepsilon_2 - M)}{(\varepsilon_1 + M)(\varepsilon_2 + M)} \right]^{-\frac{1}{2}} \quad \text{(B.1)}$$

$$\mathrm{T} = \left| (\varepsilon_1 + M)(\varepsilon_2 + M) \right| \quad \text{(B.2)}$$

$$\Xi = \left| (\varepsilon_1 - M)(\varepsilon_2 - M) \right| \quad \text{(B.3)}$$

Because of the threshold condition that we established at the end of Section 3 (equations (21) and (22)), the three expressions above are positive.

From (21) and considering the signs of (A.1), (A.2) and (A.3), we obtain the partial differential of the threshold with respect to the percentage of expenditure in manufacturing, μ, and with respect to the elasticity of demand for any variety and the elasticity of substitution between any two varieties of manufacturing, σ:

$$\frac{d\phi_W}{d\mu} = \frac{1}{2} F \frac{\left[-\left(\frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1} \right) \frac{1}{\sigma} (\varepsilon_2 - M) - \left(\frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1} \right) \frac{1}{\sigma} (\varepsilon_1 - M) \right] \mathrm{T}}{T^2} - \frac{1}{2} F \frac{\left[\left(\frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1} \right) \frac{1}{\sigma} (\varepsilon_2 + M) + \left(\frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1} \right) \frac{1}{\sigma} (\varepsilon_1 + M) \right] \Xi}{T^2} < 0 \quad \text{(B.4)}$$

$$\frac{d\phi_W}{d\sigma} = \frac{1}{2} F \frac{\left[\left(\frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1} \right) \frac{\mu}{\sigma^2} (\varepsilon_2 - M) + \left(\frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1} \right) \frac{\mu}{\sigma^2} (\varepsilon_1 - M) \right] \mathrm{T}}{T^2} - \frac{1}{2} F \frac{\left[-\left(\frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1} \right) \frac{\mu}{\sigma^2} (\varepsilon_2 + M) - \left(\frac{\rho-1}{\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1} \right) \frac{\mu}{\sigma^2} (\varepsilon_1 + M) \right] \Xi}{T^2} > 0 \quad \text{(B.5)}$$

Proceeding in the same way, we can obtain the partial derivative of the threshold with respect to the different parameters related to the service sector (the elasticity of demand for any variety and the elasticity of substitution between any two varieties of services, ρ; the quantity of skilled labor required to produce services, λ; and the units of services that manufacturing companies consume as fixed inputs, γ):

$$\frac{d\phi_W}{d\rho} = \frac{1}{2} F \frac{\left[-\left(\frac{\gamma\lambda/\alpha}{\left(\left(1+\gamma\lambda/\alpha\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_2-M)-\left(\frac{\gamma\lambda/\alpha}{\left(\left(1+\gamma\lambda/\alpha\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_1-M)\right]\mathrm{T}}{T^2} - \frac{1}{2} F \frac{\left[\left(\frac{\gamma\lambda/\alpha}{\left(\left(1+\gamma\lambda/\alpha\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_2+M)+\left(\frac{\gamma\lambda/\alpha}{\left(\left(1+\gamma\lambda/\alpha\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_1+M)\right]\Xi}{T^2} < 0 \quad \text{(B.6)}$$

$$\frac{d\phi_W}{d\lambda} = \frac{1}{2} F \frac{\gamma}{\alpha} \frac{\left[\left(\frac{\rho(\rho-1)}{\left(\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_2-M)+\left(\frac{\rho(\rho-1)}{\left(\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_1-M)\right]\mathrm{T}}{T^2} - \frac{1}{2} F \frac{\gamma}{\alpha} \frac{\left[-\left(\frac{\rho(\rho-1)}{\left(\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_2+M)-\left(\frac{\rho(\rho-1)}{\left(\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_1+M)\right]\Xi}{T^2} > 0 \quad \text{(B.7)}$$

$$\frac{d\phi_W}{d\gamma} = \frac{1}{2} F \frac{\lambda}{\alpha} \frac{\left[\left(\frac{\rho(\rho-1)}{\left(\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_2-M)+\left(\frac{\rho(\rho-1)}{\left(\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_1-M)\right]\mathrm{T}}{T^2} - \frac{1}{2} F \frac{\lambda}{\alpha} \frac{\left[-\left(\frac{\rho(\rho-1)}{\left(\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_2+M)-\left(\frac{\rho(\rho-1)}{\left(\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_1+M)\right]\Xi}{T^2} > 0 \quad \text{(B.8)}$$

Finally, we obtain the partial derivative of the threshold with respect to the fixed units of skilled labor employed by manufacturing firms, α.

$$\frac{d\phi_W}{d\alpha} = \frac{1}{2} F \frac{\lambda\gamma}{\alpha^2} \frac{\left[-\left(\frac{\rho(\rho-1)}{\left(\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_2-M)-\left(\frac{\rho(\rho-1)}{\left(\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_1-M)\right]\mathrm{T}}{T^2} - \frac{1}{2} F \frac{\lambda\gamma}{\alpha^2} \frac{\left[\left(\frac{\rho(\rho-1)}{\left(\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_2+M)+\left(\frac{\rho(\rho-1)}{\left(\left(1+\frac{\gamma\lambda}{\alpha}\right)\rho-1\right)^2}\right)\frac{\mu}{\sigma}(\varepsilon_1+M)\right]\Xi}{T^2} < 0 \quad \text{(B.9)}$$

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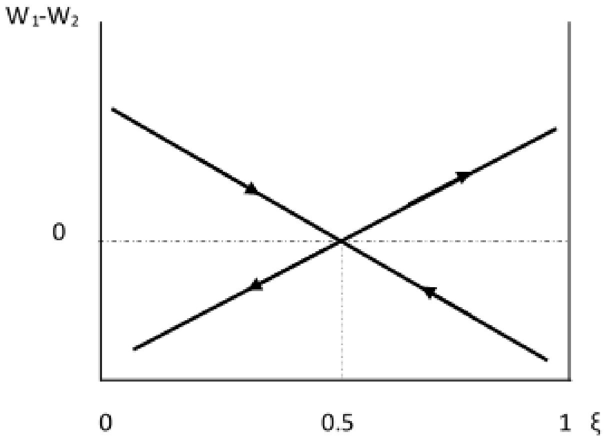

Figure 1. Stability of the equilibrium in Krugman's (1991) model

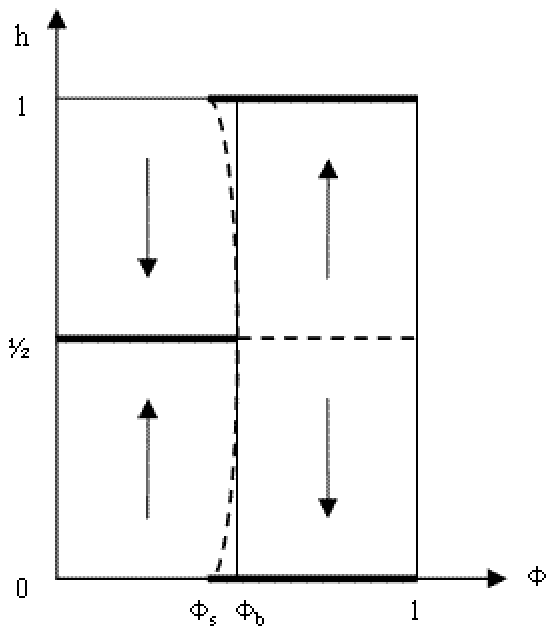

Figure 2. Bifurcation diagram

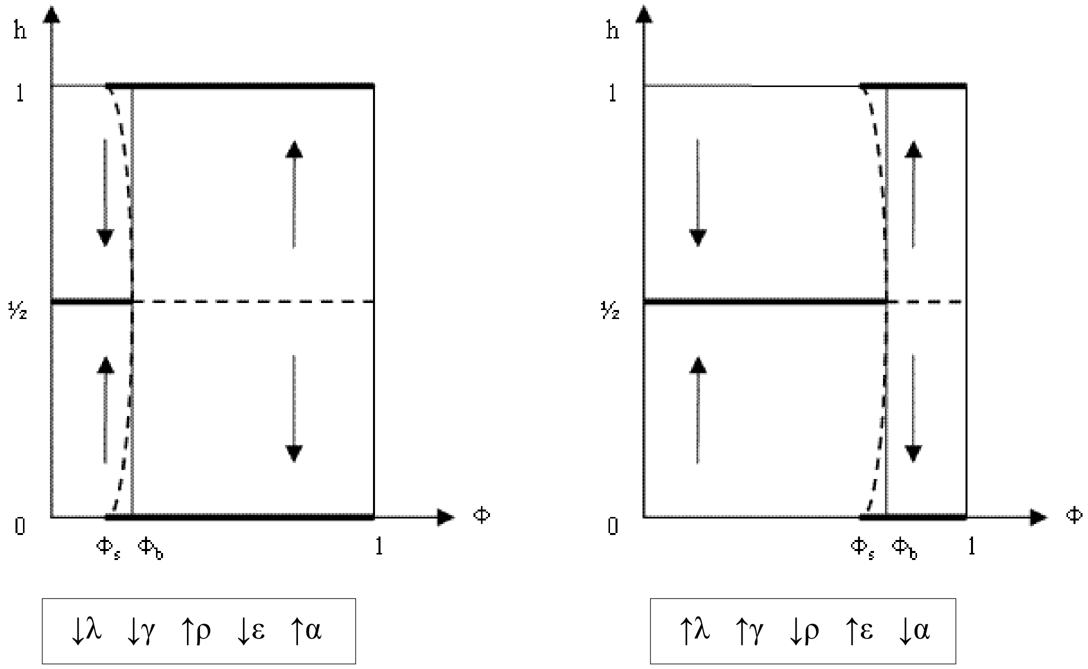

Figure 3. Effects of the parameters of the service sector

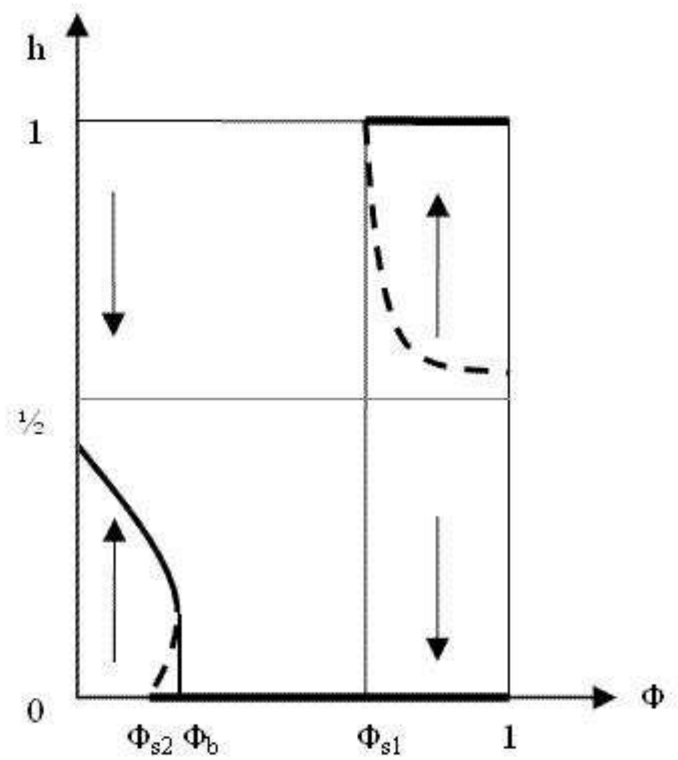

Figure 4. High percentage of skilled workers in manufacturing in both regions, but it is higher in region 1

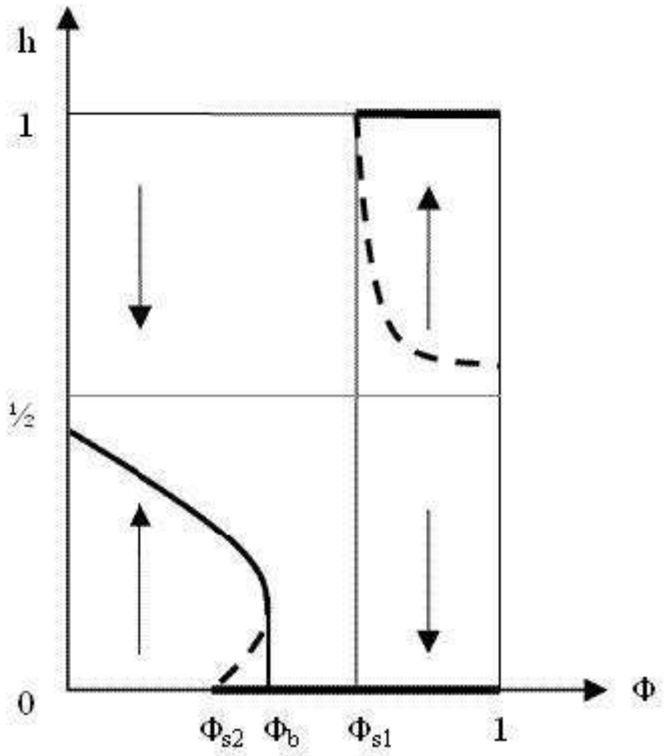

Figure 5. High percentage of skilled workers in manufacturing in region 1