


# An Evolutionary Game to Model Offshoring and Reshoring of Production Between Developed and Developing Countries

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## ABSTRACT

A dynamic model is proposed to describe the time evolution of production location choices of a multinational enterprise that can decide between two possible manufacturing locations: a stylized developed economy and a developing economy. The model is based on an evolutionary approach according to a replicator dynamics driven by expected profits. The production in each country is determined by the availability of labor inputs and their relative productivity, on wages of skilled and unskilled workers, as well as on cost externalities due to knowledge spillovers and public goods availability. The model includes the effects of relative demand and supply on earnings distribution with two different types of workers (high and low skilled) and the substitution between the two categories is captured by a CES aggregate production function. Behavioral parameters are also considered, such as the cognitive bias that overestimates the convenience of offshoring in term of labor cost and the “made in” effect that brings consumers to pay higher prices for products manufactured in a developed country.

## KEYWORDS

Dynamic Complexity, Evolutionary Games, Labor Productivity, Manufacturing Location, Offshoring, Reshoring

## 1. INTRODUCTION

Companies are increasingly expanding their operations beyond their national borders by relocating certain value chain activities abroad. They are able to fragment operations internationally, locating each stage of production in countries where they can be performed at lower cost or in a more efficient way. At the same time, they diffuse ideas and knowledge of new products and spread technology-advanced processes around the globe.

Multinational Enterprises (MNEs) are key players of the globalization process, as they have largely exploited the benefits coming from a greater interdependence of markets, ensuring great economies of scale in production, distribution, marketing and management, see e.g. Levitt et al. (1983). In this respect, the new economic geography (NEG), originated by the seminal contribution

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by Krugman (1991) and based on imperfect competition with increasing returns to scale, factor mobility, presence of trade and transportation costs, constitutes an important stream of literature for the study of the geographic distribution of industrial activity. Multinational Enterprises often offshore their manufacturing activities in developing economies, attracted by cheaper labor costs, cheaper raw materials, lower taxes and lenient legislations. However, technological developed countries may be attracting because of higher labor productivity due to advanced R&D, larger presence of skilled workers and industrial districts endowed with efficient infrastructures and cost-reducing R&D spillovers, and this may erode the initial cost-advantage of offshoring and consequently cause reshoring of firms towards developed countries.

Figure 1 shows a survey of Eurostat on European enterprises. It was asked what are the main motivational factors for international sourcing, namely the total or partial movement of business functions (core or support business functions) currently performed in-house, or currently domestically sourced, by the resident enterprise to either non-affiliated (external suppliers) or affiliated enterprises located abroad (Sunjka and Papadopoulos, 2019). We can see that one of the main driver of offshoring is the reduction of labor costs (for almost 90% of the firms interviewed), followed by the reduction of other costs, and the strategic decisions taken by the group head. In the following, we will discuss more in detail what might be the strategic motivations behind this latter factor, referring to e.g. Hymer (1960), Dunning (1979). Of lesser importance are market driven factors such as access to new markets, improved quality and introduction of new products. In addition, access to specialized knowledge/technologies and the research of qualified labor are not, on average, the most relevant motivation for international outsourcing or offshoring.

Conversely, Figure 2, drawn from the same Eurostat database, highlights the main motivational factors for European enterprises to move back (i.e. reshoring) functions from abroad. In this case, strategic decisions of group head account for almost the totality of the sample (more than 90%), followed by insufficient quality of products/services and infrastructures, lack of qualified personnel and lower labor productivity at the foreign location. The majority of the causes/driver of reshoring focuses on the scarce labor productivity, on the lack of public goods, qualified workers, networks and technology offered by the low-labor cost foreign economies.

Inspired by a recent paper by Radi et al. (2021) and drawing on the NEG background, we propose a dynamic model based on an evolutionary (or adaptive) approach according to a replicator dynamics

Figure 1. Motivational factors important for enterprises sourcing internationally (2014-2017), experimental statistics. Source: survey from Eurostat (iss\_18sodest), Sunjka and Papadopoulos (2019)

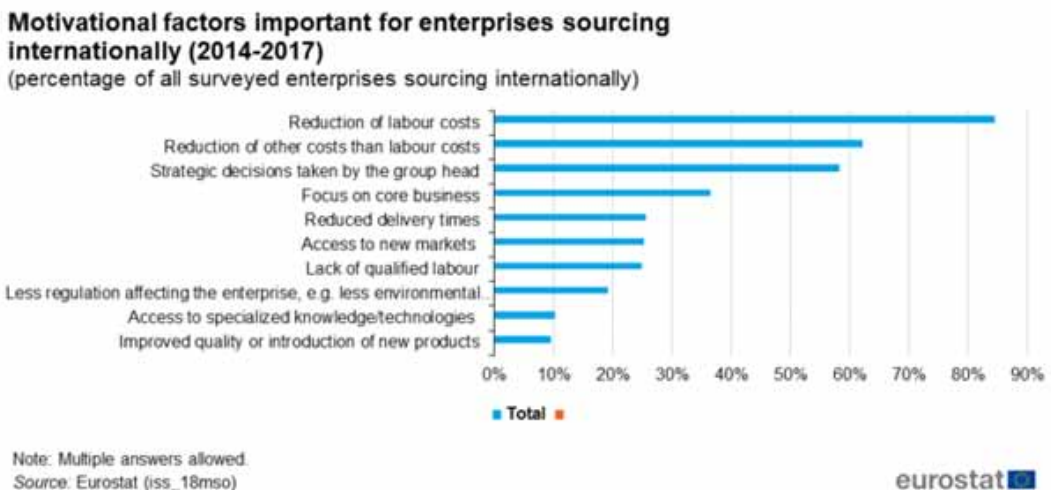


Figure 2. Motivational factors important for enterprises to move functions from abroad (2014-2017), experimental statistics. Source: survey from Eurostat (iss\_18sodest). Sunjka and Papadopoulos (2019)

**Motivational factors important for enterprises to move functions from abroad (2014-2017)**  
 (percentage of all surveyed enterprises sourcing internationally)



Note: Multiple answers allowed.  
 Source: Eurostat (iss\_18bfmot)



driven by MNE expected profits. We partially depart from NEG point of view, as we focus on the impact of the manufacturing comparative advantages of the offshoring and reshoring process, and we assume that the entire production of the industry is sold in a single common market at a price  $p$  according to a given demand function. In other words, diverging from models considered in the NEG line of research, where location patterns are market driven, in this paper we assume that the supply-side factors mostly condition the location decision, in line with the results shown in the previous figures, where the majority of motivations are supply-side factors.

The literature on International Business identifies two classes of factors that affect location choices: the agglomeration drivers and the endowment drivers, see Alcácer et al. (2013). Endowment drivers are location traits that could become location advantages for the firm such as availability of physical infrastructure, quality of the labor force, low-labor cost and limited cultural distance, see, e.g., Coughlin et al. (1991), Flores and Aguilera (2007). Agglomeration drivers account for positive externalities that derive from the geographical clustering of manufacturing activities, for example, due to technological spillovers, access to specialized labor and access to specialized intermediate inputs, see Marshall (1982). Then, according to this approach, the presence of knowledge spillovers is country-specific but also depends on the location choice of firms. These agglomeration economies have been studied with formal models, see, e.g., Bischi et al. (2003a,b), Bischi et al. (2018), and empirically documented, see, e.g., Carlton (1983), Mariotti et al. (2010).

Furthermore, in this paper we also consider a stream of literature dealing with skill-bias technical change, employing the so-called canonical model of skill differentials or two-factor model, see e.g. Acemoglu and Autor (2011), Autor and Dorn (2013). In the canonical model, the effects of relative demand and supply on the earnings distribution are typically modeled in an environment with two different types of workers (high and low skilled) and competitive labor markets. In addition, the substitution between the two categories of workers is often captured by using a constant elasticity of substitution (CES) aggregate production function. Following these papers, we introduce a CES production function with skilled and unskilled labor force to describe the aggregate production of an industry, but diverging from them we do not assume the presence of perfect competitive labor markets in determining wages.

Indeed, coherently with NEG framework based on imperfect competition, in our work MNEs have market power and compete in an environment characterized by monopolistic competition with the presence of increasing (or decreasing) return to scale. It follows that firms are able to make positive profits in the long-run and the expected profit advantages drive their choices towards a manufacturing location or another. In this vein, Hymer (1960), in one of the milestone work on this topic, claimed that capital movements are not only motivated by differences in interest rates, but there are two other main causes of international operations. Firstly, firms control enterprises in many countries in order to remove or reduce competition between them when the enterprises sell in the same market or sell to each other under conditions of imperfect competition. In other words, the movements of capital and production are motivated by the desire to achieve control. It is one of the strategic decision aforementioned: the objective is to increase the market power and market shares to gain positions of strength within the industry (on oligopolistic structure see e.g. Bacchiocchi et al., 2022).

Secondly, firms undertake operations in foreign country in order to fully appropriate the return of certain abilities they possess. They choose to manufacture directly in the country through foreign direct investment (FDI), rather than alternative methods such as licensing or subcontracting, because the imperfections of the market prevent the fullest realization of profits unless the firm exercise some control. For this reason, to exploit entirely the ownership advantage, labelled in the “ownership, location, internalization (OLI)” paradigm by Dunning (1979), the MNE should establish a critical amount of its value chain activities in the foreign country. In particular, we state that the more production is concentrated in one location the greater are the chances for the MNE to exploit the owners’ competitive advantages characterized by the intangible, valuable and organizationally embedded assets, such as strong brand name, great reputation, unique technological capabilities, huge economies of scale etc.

However, for firms, the relocation of manufacturing activities is not an easy task. The challenges can include, but are not limited to, possible language barriers, several transportation and communication costs, political risks, lack of knowledge of business trends that are common among the local consumer markets. In Figure 2, this motivation, i.e. difficulty to manage due to physical distance, language and cultural differences related to the foreign country, accounts for almost the half of the European enterprises that perform reshoring of the activities. Following the literature on international production theory, we consider these costs and the presence of different types of barriers such as cultural, geographical and social/political distances (i.e. liability of foreignness).

Along with physical barriers and costs, we also capture, through a behavioral parameter, the cognitive bias that can arise in the decisions of relocating activities. In this regard, often the group head of enterprises tends to overestimate the convenience in term of labor cost offered by the offshoring economy. Indeed, it is not by coincidence that this motivation appears, in Figure 1, as the first driver to offshore production. We will prove that this could lead to biased location decision that reduces the profit of the MNE.

Furthermore, it is often observed a psychological bias called “made in” or “country-of-origin” effect (COE) that brings consumers to prefer products/services manufactured in the home country (Schooler, 1965, Morello, 1984, Cai et al., 2002). This behavioral effect allows enterprises to charge a higher price for the product whenever is produced in the country of origin, thus influencing firms’ location decision.

Furthermore, we will show that the location process is influenced by the industrial sector to which it belong the MNE. Figure 3 reports empirical evidence on the offshoring and reshoring process, in terms of direct investment position (outwards FDI), for European enterprises in the 27 member countries from 2015 to 2019. The process is differentiated among economic sectors. In some industries like food products and beverage, computer and electronics, metal and machinery products there is a reshoring trend, even though with a diverse extent. For textile, wearing apparel, woods, paper products and construction sectors it appears a moderate offshoring tendency, whereas for other

industries such as petroleum, chemical, pharmaceutical and plastic products, motor vehicles and other transport equipment the trend has changed over the time span considered, as shown in Figure 3.

It is clear that it is not possible to draw a general conclusion about the offshoring/reshoring process in the recent period, as each economic sector has its own peculiarities that influence the trend.

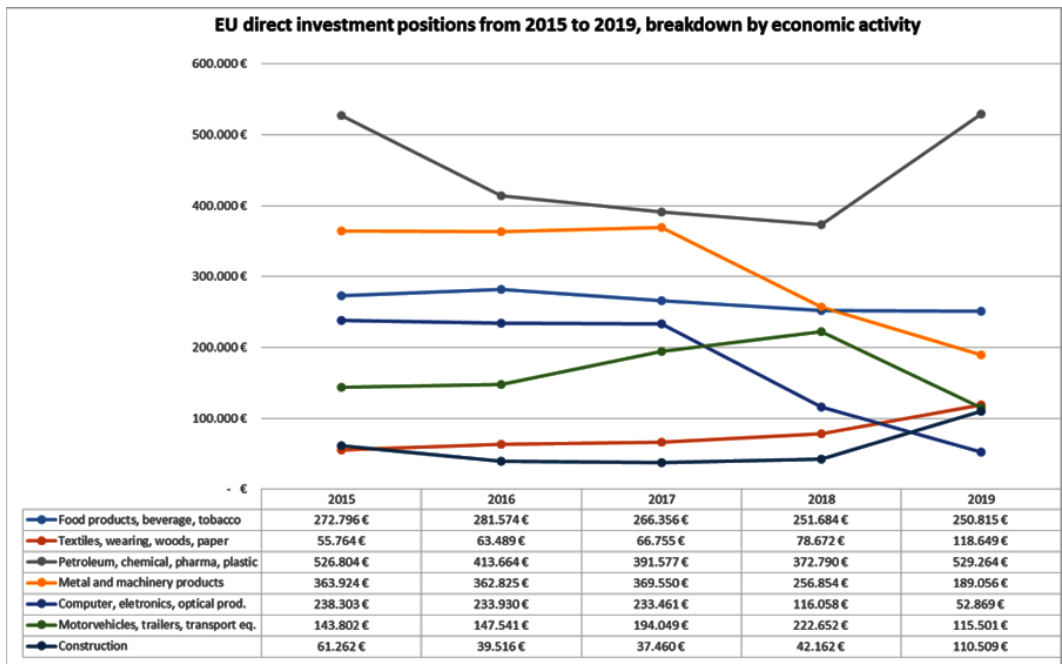
To account for this, we decided to extend the model in Radi et al. (2021) in several ways.

First, we include an analysis of the industry of reference. Each economic sector has a diverse technology, employs in a different way (i.e. intensity) its factories of production. This is reflected on the location choices of the firms, see e.g. Figure 3.

Second, there is a clear distinction in terms of marginal products and salaries between specialized and non-specialized workers. The way in which each sector makes use of them is peculiar of the type of technology employed, think e.g. to computer, electronics or chemical industries, where a great amount of high-skilled and specialized workers is employed in production, while in other economic sectors low-skilled workers are more abundant. For this reason, it becomes relevant to distinguish between these two typologies of labor inputs. As we have seen in Figures 1 and 2 that labor productivity and cost of labor are the main drivers of manufacturing location choices, the industrial technology has indubitably a strong impact on this decision. For example, technological advanced industries will be more interested in locations that offer higher labor productivity and cheaper wages for high-skilled workforce, strong industrial districts and technological spillovers etc., while less technological sectors will primarily looking for locations that grant abundant availability of relatively less-skilled labor force at cheap salaries and lenient legislations.

In this regard, the model presented in this paper is flexible enough to include and simulate different typologies of industries, trying to offer a micro foundation of the economic drivers behind international operations.

Figure 3. EU-27 direct investment positions (outwards FDI) for economic activity (BPM6), from 2015 to 2019. Source: our elaboration on Eurostat data <https://ec.europa.eu/eurostat/web/economic-globalisation/globalisation-in-business-statistics/foreign-direct-investments>



Third, physiological and behavioral factors are included in this model as they might have a non-negligible impacts on MNEs location decisions.

The plan of the paper is the following. In section 2, we describe the industry where the firms compete introducing the aggregate production function in a two-country framework. In section 3, we develop the evolutionary model that defines the adaptive manufacturing location choice of a representative MNE within the industry. Section 4 provides a dynamic analysis of the system, highlights several possible scenarios and it points out the economic drivers that influence each location decision. Section 5 expands the model by including two behavioral parameters that capture cognitive bias in evaluation of labor cost and demand perception (i.e. “made in” effect), which are frequent in international operations.

## 2. THE INDUSTRY

Consider an industry that produces goods and services on large scale, and the firms in this industry can choose between two possible manufacturing locations (countries) indexed by  $i = 1, 2$ . The first stylized country is a developed economy, a technological-advanced country, while the second one is a developing economy, a technological-laggard country.

The aggregate production of the sector is driven by the availability of labor inputs and their relative productivity. We will neglect capital as input throughout the work because we assume that the amount required in production, and its cost, are the same independently of the manufacturing economy. Given this simplifying assumption, capital is not a driver of relocation and consequently does not enter in the decisions of the firms of the industry. Since there are two possible manufacturing countries (the developed and the developing one), the constant elasticity of substitution (CES) aggregate production function for the industry is given by:

$$Y_i = \left[ (A_{Li} L_i)^{\rho_i} + (A_{Hi} H_i)^{\rho_i} \right]^{\frac{1}{\rho_i}} \quad i = 1, 2 \quad (1)$$

where the overall quantity manufactured  $Y_i$  in the sector of country  $i = 1, 2$  is a function of the availability of the two inputs employed in the production: low-skilled labor  $L_i$  and high-skilled labor  $H_i$ , both positively correlated with the production amount, i.e. an increase of the industrial employment in a given region  $i$  contribute to boost the volume of final product.

In the following we assume that  $L_2 > L_1 > H_1 > H_2$ , namely highly specialized (and educated) workers are scarcer than low-skilled workers. Indeed, in every country it is relatively easier to incur in standard workforce rather than professionals endowed with high specialization levels and relevant expertise. Such scarcity is even more pronounced in developing economy 2 that, by definition, has less advance training and educational systems.

Concerning non-specialized labor force, we claim that it is more abundant in country 2, since there are more people willing to work at the current salaries due to poor economic conditions. For this reason, the production function of the industry in developing economy 2 has relatively more low-skilled workers and less high-skilled workers employed than developed economy 1, in order to produce the same amount of product  $Y$ .

The amount of workers of each category employed in production is constant. This introduces two relevant simplifying assumption. The first is that the industry is not allowed to employ labor from other economic sectors (no inter-sectorial occupation). We can think that the labor force from other sectors has different skills and competence, which cannot be used in the industry considered.

The second is that even within the industry is not possible for a low-skilled worker to become a high-skilled worker and vice versa (no intra-category occupation). There is no interchangeability

of role if not via a proper and long-lasting professional formation (especially for moving up the ladder), but this requires training and the building of competence and expertise, which only after a considerable period of time can be acquired.

Following these assumptions, also the overall occupation of workers in country  $i$ ,  $i = 1, 2$ , that we define as  $E_i = L_i + H_i$ , does not change over time.

The positive parameters  $A_{Li}$  and  $A_{Hi}$  measure, respectively, the productivity of low-skilled and high-skilled workers in country  $i$ . Coherently with theoretical and empirical studies, the labor productivity, measured by the amount of goods and services that a group of workers produces in a given period of time, is greater on average for highly-educated labor force (thanks to a superior knowledge, skills and specialization) than for less skilled and trained workers ( $A_{Li} < A_{Hi}$ ). Furthermore, empirical evidence shows that, on average, labor productivity tends to be higher in developed and technological-advanced economy than in developing and technological-laggard ones.

Despite the productivity differential, both kinds of labor inputs are required to manufacture in this industry (Fallon and Layard, 1975, Chen, 2020). In particular, the elasticity of substitution between skilled and unskilled workers is defined as the percentage change in relative demand for low (high) skilled workers per percentage change in the relative price of high (low) skilled workers. In CES production functions (1), the elasticity of substitution between the two inputs is constant by definition, and given by:

$$\sigma_i = \frac{1}{1 - \rho_i}, \rho_i \in (-\infty, 1) \quad i = 1, 2 \quad (2)$$

Skilled and unskilled workers in country  $i$  are “gross substitutes” when the elasticity of substitution  $\sigma_i > 1$  (or  $\rho_i > 0$ ), and “gross complements” when  $\sigma_i < 1$  (or  $\rho_i < 0$ ).

When two productive inputs are gross substitutes, a reduction in supply of one creates added demand for the other. When inputs are gross complements, a reduction in supply of one reduces demand for the other. Thus, the parameters  $\rho_i$  represent the technology of production of the industry in country  $i = 1, 2$ , consisting in the way in which inputs are combined for the production of the final good or service  $Y$ . The elasticity of substitution between these two skill types is central to understanding how changes in relative supplies affect skill premia.

In our model, as previously mentioned, we stress the irreplaceability of inputs: both are needed to manufacture and they complement one other, hence  $\rho_i < 0$ .

As we refer to the same industry in the two countries, the manufacturing technology is similar, if not the same, in the two production functions considered in (1). Indeed, a breakthrough technology would be almost immediately adopted by the industry in all the manufacturing locations involved. In addition, when we consider a period of time sufficiently wide the heterogeneity in technology tends to be flattened. Nevertheless, we can imagine situations with  $\rho_i, i = 1, 2$  slightly different, caused by minor technological innovations evolved only in one country, or partial inability of the firms settled in a given location to fully exploit the technological changes taking place in the industry.

Given the CES production function in (1), the marginal product (i.e. the contribution of an additional unit of input) of low-skilled labor ( $MP_{Li}$ ) in country  $i = 1, 2$  can be defined as:

$$MP_{Li} = \frac{\partial Y_i}{\partial L_i} = A_{Li}^{\rho_i} \left[ A_{Li}^{\rho_i} + A_{Hi}^{\rho_i} \left( \frac{H_i}{L_i} \right)^{\rho_i} \right]^{\frac{1-\rho_i}{\rho_i}} \quad i = 1, 2 \quad (3)$$

and, similarly, the marginal product of high-skilled labor ( $MP_{Hi}$ ):

$$MP_{Hi} = \frac{\partial Y_i}{\partial H_i} = A_{Hi}^{\rho_i} \left[ A_{Hi}^{\rho_i} + A_{Li}^{\rho_i} \left( \frac{H_i}{L_i} \right)^{-\rho_i} \right]^{\frac{1-\rho_i}{\rho_i}} \quad i = 1,2 \quad (4)$$

The marginal products ( $MPs$ ) represent the optimal aggregate demand for labor in the industry. The ratio between  $MP_{Hi}$  and  $MP_{Li}$  is defined in the literature as the skill premia.

Since all the parameters in (3) and (4) are positive (with exception of  $\rho_i$  at the exponent),  $MPs$  are positive too. Moreover, it is easy to realize that  $\frac{\partial MP_{Li}}{\partial A_{Li}} > 0$  and  $\frac{\partial MP_{Hi}}{\partial A_{Hi}} > 0$ , as well as the positivity of  $\frac{\partial MP_{Li}}{\partial L_i}$ ,  $\frac{\partial MP_{Li}}{\partial H_i}$ ,  $\frac{\partial MP_{Hi}}{\partial L_i}$  and  $\frac{\partial MP_{Hi}}{\partial H_i}$  that is, any gain in labor productivity or increase in occupation generates a boost in marginal products and thus a rise of production volumes.

Furthermore, when  $\rho_i$  becomes more negative the value of the marginal products grow, being  $\frac{\partial MP_{Li}}{\partial \rho_i} < 0$  and  $\frac{\partial MP_{Hi}}{\partial \rho_i} < 0$ . The economic intuition behind these two latter inequalities is straightforward: a technological improvement implies an increase of the marginal product for the same amount of inputs (i.e. labor) utilized. This means that inputs are employed more efficiently in the industry, e.g. a new machine that complements the work of employees by raising the number of goods or services produced in the same amount of time.

Lastly, the complementarity among inputs, given by the condition  $\rho_i < 0$ , implies that the cross elasticity between the two different types of labor is positive. In country  $i$ , a productivity gain for low-skilled labor force causes an increase of high-skilled marginal product  $\left( \frac{\partial MP_{Hi}}{\partial A_{Li}} > 0 \right)$ , analogously a productivity growth for high-skilled labor force entails a boost of low-skilled marginal product  $\left( \frac{\partial MP_{Li}}{\partial A_{Hi}} > 0 \right)$ . This is coherent with the fact that both inputs are necessary to produce, and the productivity improvement of one is also beneficial in terms of yield of the other one.

In this framework, technologies are *factor-augmenting*, meaning that technological change serves to increase the productivity of both low and high skilled workers (Sickles and Zelenyuk, 2019).

$MPs$  are crucial, as well as the wages of each kind of workers (they will be introduced in the next section) to understand the location patterns of the firms within the industry.

### 3. THE FIRM

In this section, we discuss the manufacturing location decision of a single firm. Within the sector, each representative firm (e.g. a MNE) can choose whether to produce in country 1 or to offshore a part of its production (even the whole production) in country 2. We assume that the firm production is normalized to one, and at each discrete time  $t \in \mathbb{N}$  the representative firm decides to manufacture the fraction  $x(t) \in [0;1]$  of its overall production in country 1 and the complementary fraction  $(1 - x(t))$  in country 2. In this decision, the representative enterprise considers the industrial marginal products  $MPs$  and wages  $w$  of each location  $i = 1,2$ . The firm production is just a relatively small



fraction of the overall product in the sector ( $Y_i$ ), and for this reason the MNE alone, even if it is an important firm, is not able to condition significantly the input (i.e. labor) market conditions. In particular, the market share of the firm in the developed country is given by  $s_1 = \frac{x}{Y_1}$ , whereas the

MNE market share in the developing economy is  $s_2 = \frac{1-x}{Y_2}$ , where both  $s_i$  are assumed to be

relatively small. However, we suppose that the company is not entirely price taker in the inputs market. Indeed, in the following we will see that its manufacturing choice  $x(t) \in [0;1]$  could in turn influence, to a small extent, the productivity and wages that the representative firm faces in the country where it produces. Accordingly, we assume the presence of agglomeration economy (or diseconomy), and we argue that only highly-specialized (or educated) labor force can exploit the benefits (or the drawbacks) arising from the concentration of manufacturing activity in a given location.

The positive externalities that derive from the geographical clustering of production and research activities due to, for example, technological spillovers, access to specialized labor and to specialized tangible and intangible assets, can enhance industrial productivity and boost the quality of these activities (Marshall, 1982).

Economic geographers have emphasized that innovation is spatially concentrated, and knowledge spillovers are geographically localized (Feldman and Kogler, 2010). Knowledge tends to accumulate in production regions (Krugman, 1991), especially if we refer at the tacit component of it, widely held by individuals and residents in the form of experiences, insights and ‘know-how’. It is typically shared through discussion, person-to-person interaction and informal contacts, and therefore difficult to capture or represent in explicitly form (Cantwell et al., 1999). It generally does not travel over large geographical distances. In the first case of agglomeration economies, the firm high-skilled workers, thanks to their greater education and specialization, are the only labor category which can really exploit the advantages in terms of R&D spillover, accumulation of knowledge and experience arising from the geographical clustering of manufacturing activities. However, the clustering of the manufacturing activity in a single location is not always beneficial. In the second and opposite case of diseconomies of localization (e.g. Maurer and Walz, 2002), the spatially concentrated growth can cause problems of congestion and overcrowding due to the poor quality and efficiency of infrastructures, facilities, physical and broadband connections, as well as educational and training systems. The aforementioned endowment-drivers are essential features of any manufacturing site, since they may have a great impact, both in positive and in negative term, on the competitiveness and productivity of multinational enterprises (Zanfei 2000, Castellani et al., 2006). Moreover, endowment-drivers are country-specific as they cannot be easily transferred from country to country and they are not easily modified in the short-run. Indeed, they depend on the level of education, the structural investments undertaken in the past, the resources invested in research, the quality of the institutions of a given region.

In this instance too, the firm high-specialized workforce is the one who suffers the most from the productivity drop given by the lack of innovation opportunities, congestion cost, undersupply of public goods, scarce quality of infrastructures, poor institutional and learning framework. Consequently, we can rewrite the productivity of high-skilled workers  $A_{Hi}$  in the two economies as follows:

$$A_{H1} = LP_1 + \beta_1 x \quad A_{H2} = LP_2 + \beta_2 (1 - x) \quad (5)$$

The exogenous component  $LP_i, i = 1,2$  corresponds to the average productivity of a high-skilled worker employed in the industry. The endogenous components  $\beta_1 x$  and  $\beta_2 (1 - x)$  represent the economy (or diseconomy) of agglomeration, and therefore are function of the location decision  $x$  of the individual firm.

As explained in the previous section, labor productivity is greater the higher is the qualification of the workforce and the more technologically advanced is the manufacturing country, thus  $A_{L2} \leq A_{L1} \leq LP_2 \leq LP_1$ .

The parameter  $\beta_i, i = 1,2$  measures the extent of the advantages (if  $\beta_i > 0$ ) or disadvantages (if  $\beta_i < 0$ ) arising from the spatial concentration of the firm production and R&D activities in a given location.

This mirrors in an increasing (or decreasing) return to scale for the representative firm that concentrates production in a certain country. In particular, as the MNE concentrates the whole production in country 1 ( $x \rightarrow 1$ ), the productivity of high-skilled workers employed in the firm production process in that economy increases (decreases), conversely the same productivity in country 2 decreases (increases). Analogously, as the MNE offshores the whole production in country 2 ( $x \rightarrow 0$ ), the productivity of high-skilled workers employed in the firm production process in that economy increases (decreases), vice versa the same productivity in country 1 decreases (increases).

Substituting equations (5) in the marginal products (3) and (4), we get:

$$\begin{aligned}
 MP_{L1} &= A_{L1}^{\rho_1} \left[ A_{L1}^{\rho_1} + (LP_1 + \beta_1 x)^{\rho_1} \left( \frac{H_1}{L_1} \right)^{\rho_1} \right]^{\frac{1-\rho_1}{\rho_1}} \\
 MP_{L2} &= A_{L2}^{\rho_2} \left[ A_{L2}^{\rho_2} + (LP_2 + \beta_2 (1-x))^{\rho_2} \left( \frac{H_2}{L_2} \right)^{\rho_2} \right]^{\frac{1-\rho_2}{\rho_2}} \\
 MP_{H1} &= (LP_1 + \beta_1 x)^{\rho_1} \left[ (LP_1 + \beta_1 x)^{\rho_1} + A_{L1}^{\rho_1} \left( \frac{H_1}{L_1} \right)^{-\rho_1} \right]^{\frac{1-\rho_1}{\rho_1}} \\
 MP_{H2} &= (LP_2 + \beta_2 (1-x))^{\rho_2} \left[ (LP_2 + \beta_2 (1-x))^{\rho_2} + A_{L2}^{\rho_2} \left( \frac{H_2}{L_2} \right)^{-\rho_2} \right]^{\frac{1-\rho_2}{\rho_2}} \tag{6}
 \end{aligned}$$

Consequently, in a dynamic perspective, the location decision  $x(t) \in [0;1]$  of the firm determines changes in labor productivity  $A_{Hi}, i = 1,2$  and in turn of marginal products (6), as the quantity of production is moved from one country to the other.

Of course, firm's profit also depends on wages, which are different according to the kind of worker considered (high or low skillness) as well as the country (developed or not). Moreover, labor productivity is a crucial long-run determinant of real wages, related to salary levels for all economic sectors, and institutional factors such as labor formalization and minimum wage (Feldstein and Martin, 2008). We can represent the wages of each category of workers in country  $i = 1,2$  as the sum of two components: an exogenous part  $w_j, j = 1,2,3,4$  and an endogenous part  $\theta_1 x; \theta_2 (1-x)$  according to:

$$w_{L1} = w_1 + \theta_1 x \quad w_{L2} = w_2 + \theta_2 (1-x) \quad w_{H1} = w_3 + \theta_1 x \quad w_{H2} = w_4 + \theta_2 (1-x) \tag{7}$$

In each country  $i = 1, 2$  labour wages are positively correlated to the domestic workforce productivity, but we do not take for granted the argument of perfect competition theory stating that wages exactly equal marginal products as in the canonical model of skill differentials (Acemoglu and Autor, 2011; Autor and Dorn, 2013). This is because the firms in our model (i.e. MNEs in an industry) have market power and compete in an environment characterized by imperfect or monopolistic competition. It follows that they are able to make positive profits in the long-run. Therefore, according to labor productivity inequalities  $A_{L2} \leq A_{L1} \leq LP_2 \leq LP_1$ , we can only state that wages are lower for less-specialized workforce and in the developing country:  $w_2 \leq w_1 \leq w_4 \leq w_3$ .

The positive parameters  $\theta_i, i = 1, 2$  represent the labor bargaining power of workers/unions in each economy and they depend on the offshoring/reshoring level of the individual MNE. In both countries, wages gradually increase as long as the representative firm concentrates production there. Indeed, increasing manufacturing activities translate into more labor required: the larger is the enterprise labor demand, the higher will be the salaries requested by the workforce to be hired. In fact, since (at least to some extent) wages come from a negotiation between workers and firms, the higher the wage rate the more labor will be supplied. Coherently with economic literature, equations (7) capture the upwards sloping supply curves of labor. We also assume that labor bargaining powers  $\theta_i, i = 1, 2$  are different in order to reflect the diversity of the labor market in the two economies considered. The responsiveness of the workforce (i.e. elasticity of supply) to changes in labor demand conditions and salaries is crucial to understand the location path of the representative MNE. Indeed, we have seen that labor productivity can increase or decrease due to human capital accumulation effects, R&D spillovers or congestion effects, which all depend on the geographically distribution of productions. This contributes to an asymmetric labour-productivity remuneration and to a bargaining power that evolves dynamically as a result of switching choices from offshoring to reshoring, or vice versa.

Given this framework, we would like to study how agglomeration economies, labor productivities and wages have impacts on the decision to relocate production of a firm within the industry. When choosing between offshoring or reshoring, the MNEs should compare at each discrete time  $t \in \mathbb{N}$  the profit possibly achievable in the developed country,  $\pi_1$ , with the profit potentially obtainable in developing country  $\pi_2$ . In particular, the choice between one location or the other is driven by the additional profits that can be obtained through relocation: a firm in any period can exploit the potential profit differential in the labor market of the two economies.

The expected unitary profits  $\pi_i, i = 1, 2$  (arising from the sale of a unit of product at the fixed price  $p$ ) of the representative firm within the industry, is given by the difference between the marginal products (6) provided by each typology of worker employed in production, times the product price  $p$ , and the unitary wages (7) paid at this workforce:

$$\pi_1(x) = p(MP_{L1} + MP_{H1}) - w_{L1} - w_{H1} \quad \pi_2(x) = p(MP_{L2} + MP_{H2}) - w_{L2} - w_{H2} \quad (8)$$

It is worth to recall that these are the profits expected by the individual firm in the two possible manufacturing locations  $i = 1, 2$ , since they take into account both the industrial parameters (price, the exogenous component of productivity and wages) and the firm-specific conditions (the endogenous component of productivity and wages).

Substituting the marginal products (6) and the wages (7) into equations (8), the expected unitary profits  $\pi_i, i = 1, 2$  can be written as:

$$\begin{aligned}
 \pi_1(x) &= p A_{L1}^{\rho_1} \left[ A_{L1}^{\rho_1} + (LP_1 + \beta_1 x)^{\rho_1} \left( \frac{H_1}{L_1} \right)^{\rho_1} \right]^{\frac{1-\rho_1}{\rho_1}} \\
 &+ p (LP_1 + \beta_1 x)^{\rho_1} \left[ (LP_1 + \beta_1 x)^{\rho_1} + A_{L1}^{\rho_1} \left( \frac{H_1}{L_1} \right)^{-\rho_1} \right]^{\frac{1-\rho_1}{\rho_1}} \\
 &- w_1 - \theta_1 x - w_3 - \theta_1 x \\
 \pi_2(x) &= p A_{L2}^{\rho_2} \left[ A_{L2}^{\rho_2} + (LP_2 + \beta_2(1-x))^{\rho_2} \left( \frac{H_2}{L_2} \right)^{\rho_2} \right]^{\frac{1-\rho_2}{\rho_2}} \\
 &+ p (LP_2 + \beta_2(1-x))^{\rho_2} \left[ (LP_2 + \beta_2(1-x))^{\rho_2} + A_{L2}^{\rho_2} \left( \frac{H_2}{L_2} \right)^{-\rho_2} \right]^{\frac{1-\rho_2}{\rho_2}} \\
 &- w_2 - \theta_2(1-x) - w_4 - \theta_2(1-x)
 \end{aligned} \tag{9}$$

where it is made explicit the dependency on the individual firm production location  $x$ .

The portion of firm manufacturing activity located in country 1, represented by  $x(t) \in [0;1]$ , is assumed to evolve in discrete time according to an exponential replicator equation (proposed in Cabrales and Sobel, 1992, see also Hofbauer and Sigmund, 2003; Radi et al., 2021):

$$x(t+1) = f(x(t)) = (1-\alpha)x(t) + \alpha \frac{x(t)}{x(t) + (1-x(t))e^{\omega[\pi_2(x(t)) - \pi_1(x(t))]} } \tag{10}$$

with  $0 \leq \alpha \leq 1$ , and  $\omega > 0$ . The dynamic model (10) describes the time evolution of manufacturing location patterns by introducing an adaptive adjustment of the share of production according to a direct comparison of expected profits in the two countries, or expected gain:

$$g(x) = \pi_2(x) - \pi_1(x) \tag{11}$$

At each discrete time, the share of production in country 1 increases (decreases) when the expected profits are higher (lower) in country 1 than in country 2. The behavioral parameter  $\omega$  represents the speed of reaction (also called intensity of choice), a measure of the reactivity of the firm in switching to the opposite location choice as a consequence of the expected payoff gain. As mentioned in the introduction, there might be cognitive bias (i.e. liability of foreignness) that condition the decision of relocation. The extreme case  $\omega = 0$  gives a constant share, being  $x(t+1) = x(t) = x(0)$ . The other extreme case  $\omega \rightarrow \infty$  corresponds to a situation where the firm immediately switches all its production in the country showing a (even negligible) higher expected profit, i.e.  $x(t) \rightarrow 1$  if  $g(x) < 0$  and  $x(t) \rightarrow 0$  if  $g(x) > 0$ .

Actually, switching location can be difficult for firms because it often implies incurring in several costs: from establishing new factories and buildings to transferring knowledge and human capital abroad. For this reason, in equation (10), we also consider a form of inertia captured by parameter  $\alpha$ : the lower the  $\alpha$ , the more difficult changing location. If  $\alpha = 0$  it is straightforward to see that  $x(t+1) = x(t)$  for each  $t$ , in other words the MNE does not change in any way its manufacturing location even if it is more convenient to switch it, whereas for  $\alpha = 1$  the MNE has the maximum location responsiveness of a country profit advantage.

It is worth to stress that the unit interval  $[0;1]$  is an invariant set, i.e. if  $x(t) \in [0;1]$ , then  $x(t) \in [0;1]$  for each  $t \geq 0$ . Moreover, it is straightforward to see that  $x^* = 0$  and  $x^* = 1$ , which correspond to “pure strategies” where all production is placed in only one country, are boundary equilibrium points. Interior equilibria exist at any  $x^*$  such that  $g(x^*) = 0$ , i.e. are characterized by identical expected profits.

To sum up, from the evolutionary model (10), the share of production of the MNE in each country  $x(t)$  is updated at discrete-time periods  $t$  and the step by step adaptive choice is based on expected profit advantages in the two countries, i.e. comparison between  $\pi_1(x(t))$  and  $\pi_2(x(t))$ .

#### 4. DYNAMIC ANALYSIS

Starting from a given location pattern at time  $t = 0$ , represented by the initial condition  $x(0)$ , the difference equation (10) defines a unique trajectory  $x(t)$ ,  $t \geq 0$ , that represents the time evolution of firm’s production decisions. In particular, we are interested in the analysis of the different long run patterns, i.e. the values of  $x(t)$  as  $t \rightarrow \infty$ , that can be obtained with different parameters’ constellations and different initial conditions.

As stated in the previous section, if a trajectory converges to an asymptotic value  $x^*$ , then this may be a boundary (pure) equilibrium  $x^* = 0$  or  $x^* = 1$ , or an interior (mixed) equilibrium  $x^* \in (0;1)$  solution of the equation  $g(x^*) = 0$ , where the gain function  $g(x)$  is defined in (11). According to the definition of the profit functions (9), in general the equation  $g(x) = 0$  cannot be analytically solved, so in order to compute the equilibrium points we must mainly rely on numerical methods. The same holds for the computation of the derivatives of the map  $f(x)$  defined in (10) in order to determine the stability of the equilibrium points as well as their changes, through local bifurcations, as the parameters of the model are let to vary. Indeed, the derivative of the map (10):

$$f'(x) = 1 - \alpha + \alpha \frac{(1-x)(1-x)\omega g'(x)e^{\omega g(x)}}{(x+(1-x)e^{\omega g(x)})^2}$$

computed at the equilibrium points becomes:

$$f'(0) = 1 - \alpha + \alpha e^{-\omega g(0)}, \quad f'(1) = 1 - \alpha + \alpha e^{\omega g(1)} \quad \text{and} \quad f'(x^*) = 1 - \alpha x^* (1-x^*) \omega g'(x^*)$$

respectively, so their analytical computation is quite involved due to the complicated expression of the gain function  $g(x)$  and its derivative  $g'(x)$ .

However, the numerical exploration of some dynamic scenarios, with parameters' constellations suggested by economic considerations, can give us some insight into the possible time evolutions of the economic system. For example, let us consider the situation shown in Figure 4, obtained with the set of parameters listed in the figure's caption, where we have only the two boundary equilibrium points:  $x^* = 0$ , unstable being  $f'(0) > 1$  (as it can easily be deduced looking at the slope of the graph compared with the slope of the diagonal), and  $x^* = 1$  which is asymptotically stable being  $f'(1) < 1$ . Moreover,  $x^* = 1$  is globally asymptotically stable, because its basin of attraction is the whole set of mixed location choices, i.e. it is reached in the long run starting from any initial condition  $x(0) \in (0;1)$ . In other words, the firm gradually moves its production to total reshoring independently of the initial mixed location choice. In Fig. 4 a generic trajectory, starting from  $x(0) = 0.2$  (i.e. 20% of the production in country 1) is graphically represented, such that the fraction of manufacturing in country 1 gradually increases and, after a few steps, the representative firm chooses to entirely produce in its home country.

The reasons behind this kind of behavior are to be sought in the firm expected profit  $\pi_1(x) > \pi_2(x)$  for every  $x$ . In economic terms, despite bearing lower cost of labor in the developing country 2, the higher productivity of the workforce employed in the country 1 completely offsets the cost convenience of lower salaries. In Fig. 4 we can also notice a relatively fast convergence towards the stable equilibrium  $x^* = 1$ .

In Figure 5(a) we show that the speed of convergence, besides the various parameters, strongly depends on the values of parameters  $\alpha$  and  $\omega$ . In fact, with all other parameters being equal (i.e. economic conditions have not changed) for lower value of these two behavioral parameters the firm's decisions approach the same equilibrium, but in a slower way. In this specific case with  $\alpha = 0.3$  and  $\omega = 0.5$ , starting from the same initial condition as in Fig. 4, a small neighborhood of the equilibrium is reached after around 25 periods instead of 5. Figure 5(b) shows the time evolution of the four marginal products (6): the green curve represents  $MP_{H_1}$  that stabilizes after the same amount of time to the value of 40. The pink curve indicates  $MP_{H_2}$  which ends up at 34. Similarly, the blue curve of  $MP_{L_1}$  reaches 16 and is well above the red curve of  $MP_{L_2}$  at 8. The graph also demonstrates

**Figure 4. Total reshoring  $x^* = 1$  globally stable equilibrium. Parameters:**  $p = 1000, A_{L1} = 0.15, A_{L2} = 0.13, \rho_1 = -0.5, \rho_2 = -0.5, LP_1 = 0.20, LP_2 = 0.16, \beta_1 = 0.08, \beta_2 = 0.03, L_1 = 200, L_2 = 220, H_1 = 90, H_2 = 80, \alpha = 0.7, \omega = 1, w_1 = 12, w_2 = 9, w_3 = 34, w_4 = 32, \theta_1 = 2, \theta_2 = 2$

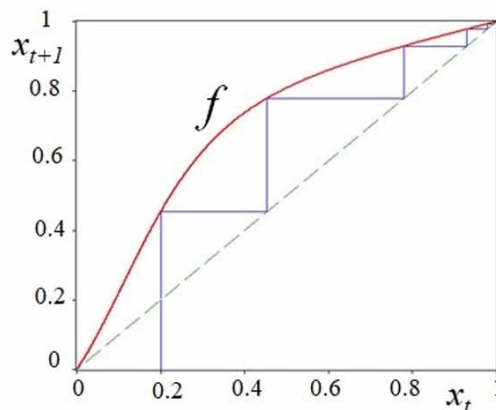
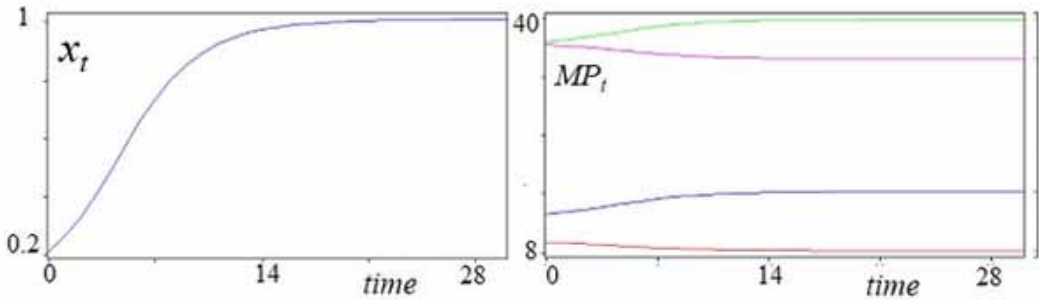


Figure 5. Time series of  $x$  and  $MP_s$  in total reshoring. Same parameters as in Fig. 4, except  $\alpha = 0.3$  and  $\omega = 0.5$



what previously stated: the gap between the productivity of the two economies is wide and in favor of country 1. It further increases due to spillovers and economy of agglomeration as long as the MNE reshores production from country 2 to country 1.

Often in the public debate there is the common perception that is always advantageous to produce in countries where legislation is more lenient and/or where the cost of labor is cheaper, overlooking the role played by the ability, competence and experience of the workers. Probably, this cognitive bias is affected by the intangible nature of the labor productivity, surely not easy to be measured, but with a strong impact on the potential revenues of the company.

Furthermore, the opportunity of exploiting greater advantages in term of technological and R&D spillovers in country 1 (*i.e.*  $\beta_1 > \beta_2$ ) is another important driver that weights, in this scenario, for the final preference of the firm towards the total reshoring of activities. It follows that developed countries represent a potential attractive destination for firms whenever they invest on the quality and on the structure of their system of training and education, in cutting-edge technology, in intangibles and tangible public goods such as widespread knowledge, networks, advanced infrastructures, sound and solid institutions. In this respect, the bifurcation diagram in Figure 6(a) is explicative of how an increase in high-skilled labor productivity  $LP_1$  can turn the tide from an equilibrium of total offshoring  $x^* = 0$  to one of total reshoring  $x^* = 1$ . It is an abrupt transition when  $LP_1$  increases because there are no internal (or mixed) equilibrium points.

Conversely, Figure 6(c) shows that a reduction in high-skilled labor productivity of country 1 ( $LP_1 = 0.17$ ) leads to a scenario where, depending on the initial condition, the firm can move to either the pure equilibrium  $x^* = 0$ , or the pure equilibrium  $x^* = 1$ . In this case, starting from the initial condition  $x(0) = 0.2$  we assist to a relatively fast convergence to the equilibrium of total offshoring.

In addition, it should not be underestimated the role of the cohesion and cooperation among economic actors (e.g. technological spillover, partnerships on supply chains between intra-sectorial and inter-sectorial firms...), and extra-economic actors (e.g. research and industrial innovations from universities, research centers to factories...). As described in section 3, this contributes to increase the source of innovations and ultimately the productivity of the firm in a country. The bifurcation diagram with bifurcation parameter  $\beta_1$  in Figure 6(b) shows this effect, as we can appreciate a gradual transition from a mixed equilibrium, where the majority of the activities is offshored, to a total reshoring of production when  $\beta_1 > 0.032$ .

Figure 6(d), obtained with  $\beta_1 = 0.03$  and all the other parameters as in Fig. 4, highlights the position of the internal stable equilibrium. Starting from the same initial condition  $x(0) = 0.2$  the system moves towards the mixed equilibrium  $x^* = 0.71$ .

This proves that in order to counteract the competition of low-wages economies it is not necessary to perform a race to the bottom of the salaries, but rather acting on the lever of developments and innovation to increase the attractiveness of a country.

This discussion contains relevant policy insights for an economic planner, such as the government, to encourage the return to country 1 of the offshored manufacturing activities.

Finally, a remark on the market shares of the MNE within the industry. In the long-run, for the parameters used in Figures 4 and 5, the industry produces  $Y_1^* = 7$  in the developed economy, and

$Y_2^* = 4.6$  in the developing economy. The market share of the representative firm are  $s_1 = \frac{x}{Y_1} = 14.3\%$

and  $s_2 = \frac{1-x}{Y_2} = 0\%$ .

In the following, we show and comment some different dynamic scenarios obtained by properly tuning the economic parameters of the model. Figure 7 provides a quite different situation: despite of the initial location of the MNE manufacturing chain, the firm's decisions always lead in the long run to opt for a total offshoring of its activities  $x^* = 0$ . If we compare the enterprise potential profits

Figure 6. Bifurcation diagrams with bifurcation parameter  $LP_1$  (panel a) and  $\beta_1$  (panel b). Phase diagram with  $LP_1 = 0.17$  (panel c). Phase diagram with  $\beta_1 = 0.03$  (panel d). All other parameters as in Fig. 4. All figures obtained with the initial condition  $x(0) = 0.2$

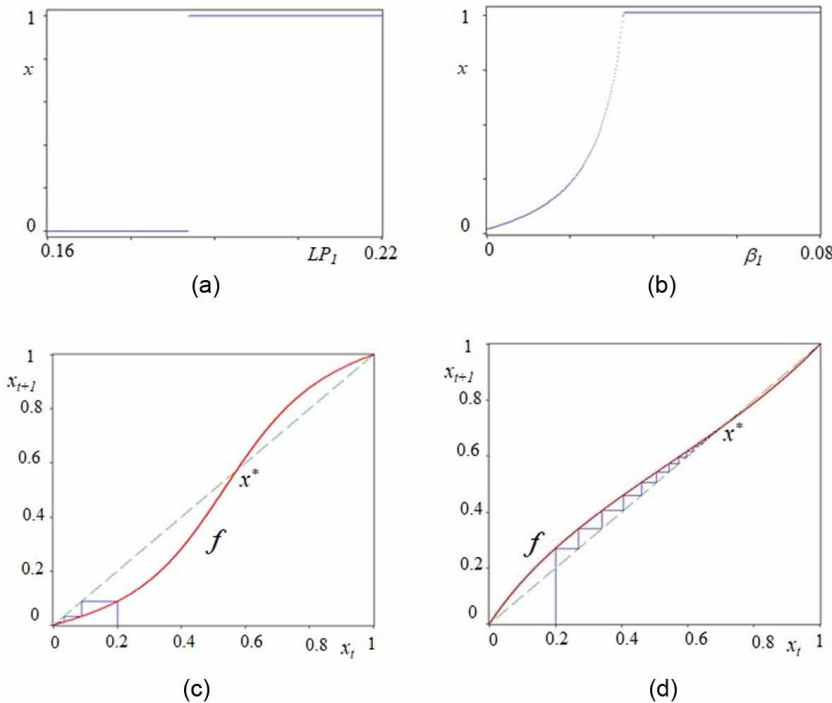
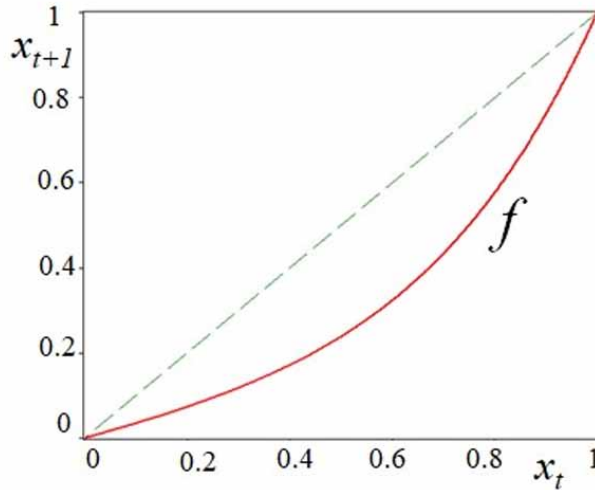




Figure 7. Same set of parameters as Fig.4 except  $A_{L2} = 0.14$  and  $\theta_1 = 3 > \theta_2$ . Globally stable equilibrium of total offshoring  $x^* = 0$



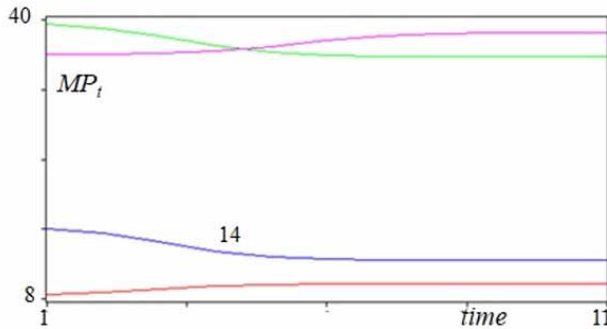
in the two economies, it results that  $\pi_1(x) < \pi_2(x)$  for every  $x$ . In particular, in the stable equilibrium, the expected profits of the firm are  $\pi_1(0) = 1.29$  and  $\pi_2(0) = 4.4$ .

Only two parameters have been changed with respect to the previous Figure 4: the productivity of low-skilled labor force in the developing country 2 has increased ( $A_{L2} = 0.14$ ) approaching that of the more technological economy, and the individual and collective labor bargaining power in the home country now has grown exceeding that of the other economy ( $\theta_1 = 3 > \theta_2$ ). These two drivers contribute to reverse the profitability in favor of the underdeveloped economy. Indeed, an increase in labor productivity (both of low and high skilled workforce, recall they are imperfect complement inputs in the production process of the firm) occurring in the developing country, can erode the initial revenue advantage of reshoring. This means that the technological-laggard country is gradually catching-up the developed economy, shrinking the differences in technology and knowledge in this particular industry.

Indeed, Figure 8, which should be compared with Figure 5(b), shows that despite the advantage of country 1 for low-skilled marginal product  $MP_{L2} < MP_{L1}$ , an inversion of trend occurs for high-skilled marginal product. In the long-run (here after 5 time periods) the economy 2, due to the benefits of firm agglomeration, overcomes the most-advanced economy 1 in high-skilled marginal products  $MP_{H2} > MP_{H1}$ . It is worth to mention that the labor productivity of high-skilled labor force is still higher in the advanced country 1 ( $LP_1 = 0.20 > LP_2 = 0.16$ ), but the gain in term of low-skilled labor productivity  $A_{L2}$  in this scenario, contributes to raise the marginal product of high-skilled workforce  $MP_{H2}$  by input complementary. The chance of taking advantage of positive economic spillover ( $\beta_2 > 0$ ) as long as the MNE moves its production in country 2, also helps to concentrate the activities in this latter location.

Analogously, a boost in labor bargain power is detrimental for the firm as implies higher salaries and hence greater cost. If it occurs in country 1, it constitutes an additional factor that plays in favor of the developing country because it further increases labor cost differentials. In this case of total

Figure 8. MPs in total offshoring. Same parameters as in Fig. 7

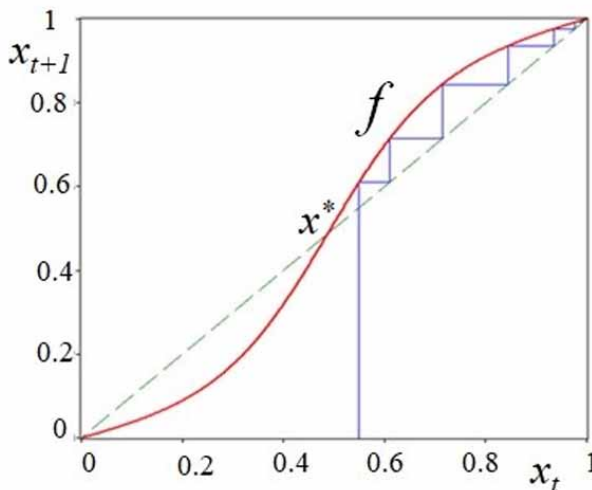


offshoring  $x^* = 0$ , the industry produces  $Y_1^* = 5.83$  in the developed country and  $Y_2^* = 5.32$  in the developing country. Thus, with respect to the previous scenario, it is evident the shift of the overall production of the industry towards the offshoring economy driven by the choice of the MNE. The market shares of the firm in the two economies now are  $s_1 = \frac{x}{Y_1} = 0\%$  and  $s_2 = \frac{1-x}{Y_2} = 18,8\%$ .

In Figure 9, ceteris paribus, we reduce the labor bargaining power of country 1, by setting  $\theta_1 = 1 < \theta_2$ . This leads to a scenario where both the options of total reshoring and total offshoring are coexisting stable equilibrium points, each with its own basin of attraction separated by the unstable interior equilibrium.

This implies a phenomenon of path dependence, because the initial MNE location choice (i.e. the history) matters in order to select the long run outcome. In the specific case of Figure 9, if the firm has already more than an half of its manufacturing activities in the country 1 then the final choice will be to exploit the agglomeration benefits in this economy through a total reshoring  $x^* = 1$ . This

Figure 9. Unstable internal equilibrium  $x^* = 0.5$  and both stable boundary equilibria. Same parameters as in Fig. 7 except  $\theta_1 = 1 < \theta_2$

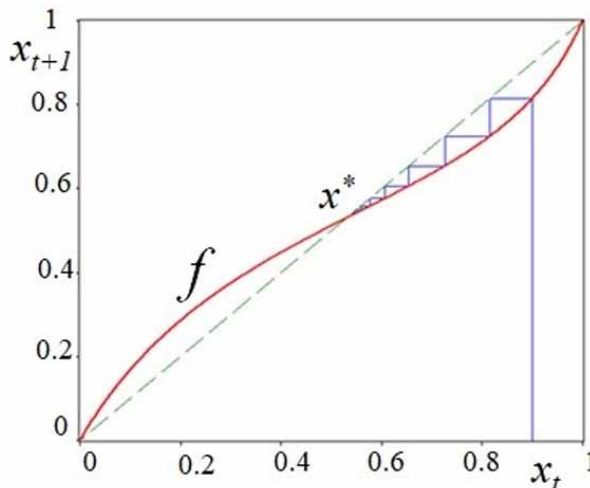


is shown by the trajectory starting from  $x(0) = 0.55$  outlined in Fig. 9, that gradually converges towards the total reshoring equilibrium. However, if the company has initially settled more than 50% of its supply chain in the developing country 2, i.e.  $x(0) < x^* = 0.5$ , then it is more profitable to remain there, to avoid the risk of losing advantages already acquired in country 2. Thus, the firm will opt for total offshore  $x^* = 0$  in the long-run. Indeed, in this dynamic scenario the internal equilibrium  $x^* = 0.5$  is unstable (the derivative  $f'(x^*) > 1$ ) and represents a separator (a watershed) between the basins of attraction of the two stable boundary equilibria. Of course the position of the interior equilibrium, hence the size of the two basins, depends on the values of the economic parameters, i.e. from the economic policies adopted. For example, the existence of this separator is related with the fact that the positive effect on firm's revenue coming from the agglomeration of activities ( $\beta_1$  and  $\beta_2$ ) exceeds the negative impact associated with increase in firm labor demand and consequently in wages ( $\theta_1$  and  $\theta_2$ ). In fact, salaries grow with the concentration of the production in one location, but at a slower pace than labor productivity gains. Obviously, depending on the equilibrium reached in the long-run, the firm market shares and the industry production are different. In the case of total reshoring  $x^* = 1$ , the industry produces  $Y_1^* = 6.97$  in country 1 and  $Y_2^* = 4.81$  in country 2, the MNE market share are  $s_1 = 14.3\%$  and  $s_2 = 0\%$ . If the firm opts for total offshoring  $x^* = 0$ , the industry produces  $Y_1^* = 5.79$  in country 1 and  $Y_2^* = 5.33$  in country 2, the MNE market share are  $s_1 = 0\%$  and  $s_2 = 18.8\%$ .

In the next Figure 10, we move to another interesting situation. By increasing the labor bargaining powers in the two economies  $\theta_1 = 3$  and  $\theta_2 = 4$ , with all the other parameters fixed as in the Figure 9, the dynamic behavior of the firm becomes completely different.

Now the interior equilibrium point  $x^*$  is stable ( $-1 < f'(x^*) < 1$ ) and the two boundary equilibria are unstable, being the slope of the graph greater than 1 in both these points. So, the only (global) attractor of the system is the internal stable equilibrium  $x^* = 0.53$ , where the expected profits in the two countries are equal:

Figure 10. Stable internal equilibrium  $x^* = 0.53$ . Same parameters of Fig. 9 except  $\theta_1 = 3, \theta_2 = 4$ .

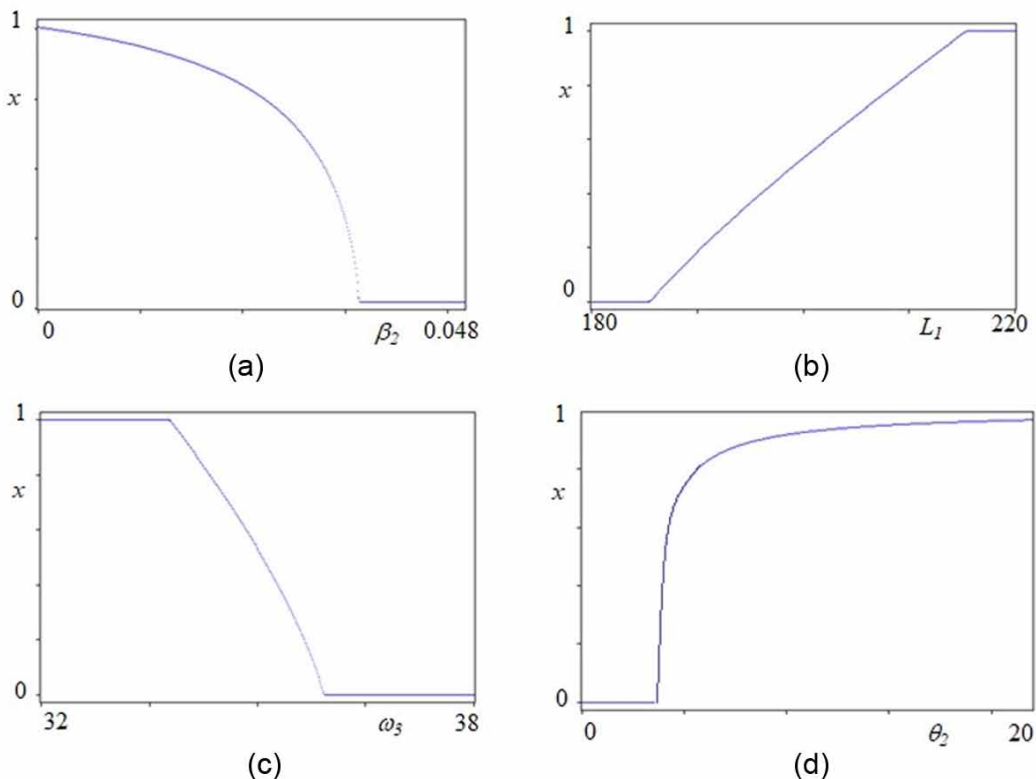


$$\pi_1(0.53) = \pi_2(0.53) = 2.59$$

When the sequence of location decisions  $x(t)$  reaches this equilibrium, for example starting from the initial condition  $x(0) = 0.9$  as in Figure 10, an optimal situation is get, as there is no further motivation to relocate. The enterprise splits its manufacturing activities in the two countries, and precisely 53% in the advanced country 1 and the remaining 47% in the developing economy 2. This situation arises because the revenues from labor productivity and the cost of wages, which are the main components of the firm profit functions in (8), are similar between the two economies. Besides, the advantages coming from production concentration ( $\beta_1$  and  $\beta_2$ ) are lower than the salaries growth disadvantages ( $\theta_1$  and  $\theta_2$ ) when production is completely settled in one country. For this reason, for the MNE becomes more convenient to divide the manufacturing activities between the two countries. Of course, any change in parameters (e.g. an increase or decrease of wages, in labor productivity and in bargain power, in agglomeration economies, as well as of the availability of the workforce) moves this mixed equilibrium point towards a combination where more reshoring or more offshoring is present. In Figure 11 starting from the same scenario of Figure 10, we highlight some examples.

The bifurcation diagram in Fig. 11(a) displays how an increase of agglomeration opportunities  $\beta_2$  in developing country 2 incentives the MNE to offshore a growing amount of manufacturing

Figure 11. Bifurcation diagrams with bifurcation parameters  $\beta_2$  (panel a)  $L_1$  (panel b)  $w_3$  (panel c) and  $\theta_2$  (panel d). All other parameters as in Fig. 10



activities. In diagram 11(b), when the availability and the employment of low-skilled labor force  $L_1$  in country 1 rises, the firm gradually moves its production in country 1. In diagram 11(c) we refer to the cost side, changing the wages of high-skilled workers in the first economy. As expected, a higher salary  $w_3$  pushes the MNE to offshore more in order to save in labor costs. Finally, the bifurcation diagram 11(d) depicts the impact of a labor bargaining power expansion in country 2. It is often observed that when the firms of an industry offshore production in a less-developed and cheaper economy, the negotiating power of workers in that sector rises (Foster-McGregor et al., 2016). The resultant salary increase may, in the long-run, erode the initial advantage of offshoring and persuade firms to reshore manufacturing activities.

Starting from the parameters' values of Fig. 10, we show that a boost in the behavioral parameters  $\alpha$  and  $\omega$ , respectively proxies of inertia in changing production location and reactivity of the MNE to changes in the industrial profit of the two countries, can lead to dynamic scenarios characterized by overshooting phenomena. This can be seen, for example, in the situation depicted in Figure 12, where a generic trajectory of the dynamics model (10) converges to stable periodic oscillations.

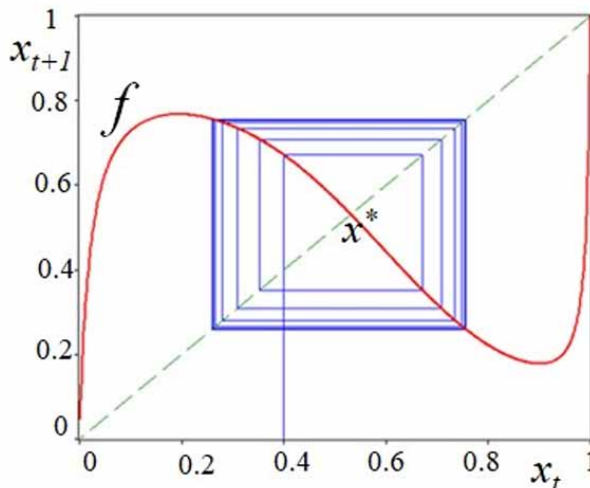
This outcome is plausible only for values of the parameter  $\alpha$  close to 1, i.e. when the cost of relocation for the firm is low (i.e. low cost of transportation, small trade and investment barriers, good knowledge of the foreign market, etc.). For any initial condition  $x(0) \in (0, 1)$ , except the interior equilibrium  $x^*$ , at each time step the time evolution of the location patterns of the MNE moves to the opposite location choice with respect to  $x^*$ , a typical overshooting effect.

An extreme form of oscillatory behavior is a chaotic location pattern, as highlighted in Figure 13.

In this case the time evolution of the firm's location decisions is described by a trajectory jumping from an offshoring quota to another in an apparently random way (even if we know it is governed by the deterministic difference equation (10)), and the attractor is called chaotic: it is densely filled by repelling periodic points and the motion inside is characterized by sensitive dependence on initial conditions (see e.g. Devaney, 1986, Lorenz, 1993, Medio and Lines, 2001).

The economic consequence of such erratic motion is a low level of predictability regarding the MNEs future manufacturing location pattern. The only information at disposal of policy makers is that trajectories are bounded into a finite trapping region bounded by the critical points of the map

Figure 12. Globally attracting cycle of period 2. Same parameters as in Fig. 10 except for  $\alpha = 1$  and  $\omega = 4$



(local minimum and maximum values, see e.g. Abraham et al., 1997). However, the trapping region where the chaotic motion is confined may almost cover the entire phase space, as it occurs in the situation shown in Figure 13. Such uncertainty may disappear acting on the primary cause of the chaotic behavior, namely the excessively MNEs responsiveness in choosing manufacturing activity location. From this point of view, a certain value of inertia in switching location (i.e. low  $\alpha$  and  $\omega$ ), even if it is sub-optimal in terms of firms' decisions due to the delay toward more efficient inputs reallocation, could be beneficial at a collective level and for policy makers as it avoids such erratic time patterns.

The bifurcation diagram in Figure 14 shows the effect of increasing values of the speed of reaction  $\omega$  on the long-run behavior (i.e. the attractor) to which a generic trajectory converges. For low values of  $\omega$  there is a globally stable interior equilibrium at  $x^* = 0.37$ , then increasing  $\omega$  over 1.5 a stable cycle of period 2 is created through a period doubling (or flip) bifurcation at which  $f'(x^*) = -1$ , then further increments of  $\omega$  lead to a 4-periodic cycle and then the well known period-doubling cascade (see e.g. Devaney, 1986), a classical route to chaos.

In Figure 15 the differential in productivity of low-skilled labor employment widen in favor of the technological-advanced country 1, whereas the industrial productivity of high-skilled workforce tapers between the two economies. However, the real novelty comes from the value of  $\beta_2$ , because now, in contrast with all the previous cases, is negative. As mentioned in section 3,  $\beta_i < 0$  means that in country  $i$  there are diseconomies of agglomeration, that may be caused by congestion effects, such as over-exploitation of resources, or the inadequacy and scarcity of public goods, or even a lack of technological and knowledge spillovers. This discourages moving all the manufacturing activity in country  $i$  (in this example  $i = 2$ ) since this choice reduces the productivity of the workers employed there. Nevertheless, if the economy 2 still has some cost advantages in terms of salaries ( $w_2 < w_1$  or  $w_4 < w_3$ ) it may happen that more than an equilibrium occurs, as highlighted in Figure 15.

**Figure 13. A chaotic attractor.** Parameters:  $p = 1000, A_{L1} = 0.15, A_{L2} = 0.14, \rho_1 = -0.5, \rho_2 = -0.5, LP_1 = 0.20, LP_2 = 0.16, \beta_1 = 0.04, \beta_2 = 0.03, L_1 = 200, L_2 = 220, H_1 = 90, H_2 = 80, \alpha = 1, \omega = 3, w_1 = 11, w_2 = 7, w_3 = 34, w_4 = 32, \theta_1 = 3, \theta_2 = 4.1$

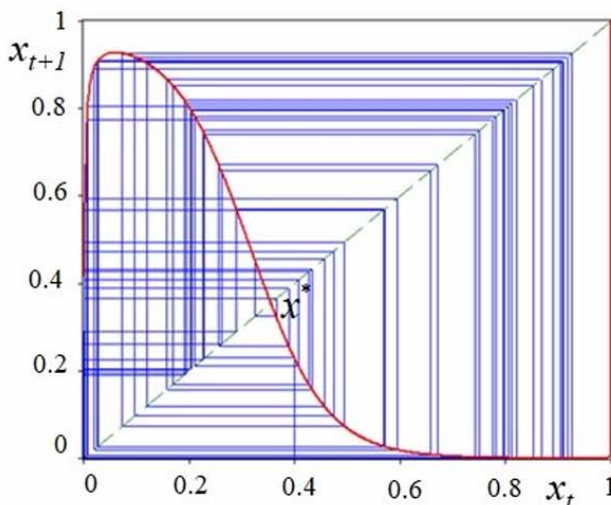
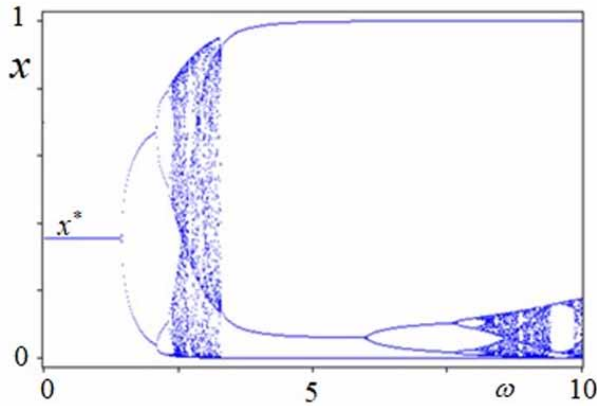


Figure 14. Bifurcation with the speed of reaction  $\omega$  used as bifurcation parameter, the other parameters are the same as in Fig. 13



We have two stable equilibria,  $x_1^* = 0$  and  $x_2^* = 0.66$ , each with its own basin of attraction, separated by the unstable equilibrium  $x_1^* = 0.27$ . In Figure 15 we also show that starting from the initial condition  $x(0) = 0.34$  the system converges to the internal equilibrium  $x_2^*$ , where the MNE divides its production between the two countries (i.e. 66% in country 1, 34% in country 2).

A crucial parameter in the offshoring/reshoring choice is  $\rho_i, i = 1, 2$ , representing the technology of production. As stressed before, each industry has a different manufacturing technology, i.e. a different way in which labor inputs are employed, and this has a strong effect on the dynamics of location decisions. Generally, the technology adopted by an individual firm is the same regardless of the place of production. The technological innovations (i.e. symmetric reduction of  $\rho_i, i = 1, 2$ ) that contribute to raise the marginal product  $MP_i$  of the firm, have a positive impact on expected profits  $\pi_i, i = 1, 2$ , in both countries, defined in (9). Nonetheless, some situations may exist where a minor technological innovation evolves only in one country, and/or the firm is partially unable to fully exploit the technological changes taking place in the industry in a particular location, thus leading to an asymmetric change in  $\rho_i, i = 1, 2$ .

For example, starting from the previous Figure 15, we can imagine a scenario where  $\rho_1$  is fixed at -1, but  $\rho_2$  undergoes small changes, as shown in the bifurcation diagram of Figure 16(a).

When  $\rho_2$  decreases, i.e. there is an innovation in developing country 2, the expect profit  $\pi_2$  increases, hence the firm may opt for a total offshorability of the activities, converging to  $x^* = 0$  as can be seen from Figure 16(b) obtained with  $\rho_2 = -1.003$ . From this scenario, where no interior equilibrium points exist, a small increase of  $\rho_2$  will lead to a fold bifurcation that creates two interior equilibria, one unstable and one stable, i.e. the situation shown in Fig. 15 where  $\rho_2 = -1$ . Further increases of  $\rho_2$  move the stable fixed point  $x_2^*$  closer and closer to the boundary equilibrium of total reshoring  $x^* = 1$  (a transcritical, or stability exchange, bifurcation). Indeed, in the bifurcation diagram 16(a), for  $\rho_2 > -0.984$  the firm chooses total reshoring  $x^* = 1$  in the long run because  $\pi_2$  has decreased.

We now move to some possible extensions of the model.

## 5. SOME POSSIBLE BEHAVIORAL BIASES IN THE LOCATION DECISION

When firms compare expected profits associated with production in a developed and in a developing country, a cognitive bias often exists given by an excessive emphasis in wages, in particular to consider the attractiveness of lower salaries in laggard economies. This bias is related with the fact that in advanced economies the production costs are mainly due to salaries because other costs (e.g. infrastructures, workers' training) are partially covered by government institutions (i.e. public goods). Instead, in developing economies these factors should be considered because they reduce the productivity of workers. However, as stressed in the previous section, often they are neglected with the risk of attributing too much importance to the convenience of cheaper wages. This cognitive bias can be included in the model proposed by introducing a weight  $\gamma$  for the salaries of country 2, in the profit function (8):

$$\pi_2^e(x) = p(MP_{L2} + MP_{H2}) - \gamma(w_{L2} + w_{H2}) \quad (12)$$

According to the underestimation bias, the parameter  $\gamma$  that weights wages should be  $\gamma < 1$ . The lower  $\gamma$ , the higher the misperception of firm' decision-makers towards an offshoring cost convenience. If  $\gamma = 1$  there are no psychological biases and the correct profit (8) is estimated by the firm.

Another common cognitive bias can be considered on the side of demand, as consumers are often inclined to pay a higher price for goods produced in a developed country with respect to those produced in a developing one, even if the technology adopted and other manufacturing features are identical. This is defined as the country-of-origin effect (COE), also known as the made-in effect or the nationality bias (Schooler, 1965, Morello, 1984, Cai et al., 2002). It is a psychological or behavioral bias that describes how consumers' attitudes, perceptions and purchasing decisions are influenced by products' country of origin image and labeling. Thus, if the entire production of the industry is sold in a single common market at a price  $p$ , consumers will be willing to pay more the products or services of the firm, the greater is the quantity manufactured in country of origin 1. This can be inserted in the model by considering an increase of price proportional to the share of production  $x$  in the home economy:

$$\pi_1^e(x) = (p + \eta x)(MP_{L1} + MP_{H1}) - w_{L1} - w_{H1} \quad (13)$$

where the parameter  $\eta$  captures the size of the "made-in" effect.

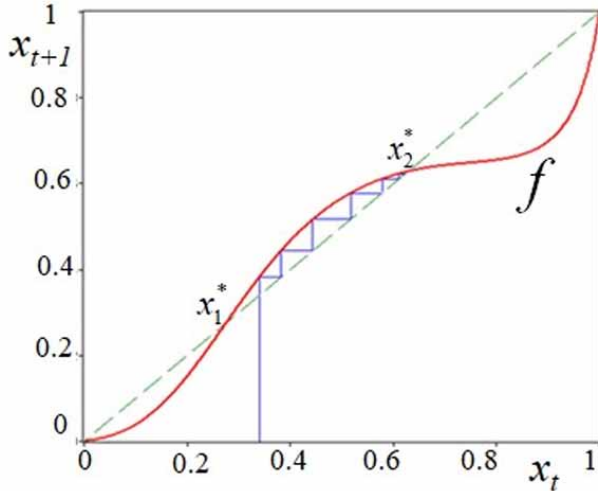
Substituting (12) and (13) into (9), and then in the model (10), we get a system with the same qualitative mathematical proprieties described at the beginning of section 4 and that allows us to explore the quantitative effects of psychological biases. For example, starting from the situation with an internal stable equilibrium as in Figure 10, we can explore the consequences of changes in the behavioral parameters  $\gamma$  and  $\eta$ . Figure 17 represents the bifurcation diagrams for  $\gamma$  (panel a) and  $\eta$  (panel b), with all the other parameters fixed as in Fig. 10.

As long as the misperception of cost efficiency increases, namely  $\gamma$  reduces in panel 17(a) moving from the right to the left, the MNE offshores a greater amount of production, up to  $\gamma = 0.98$  where the totality of activities is offshored. The transition is gradual and starts from  $x^* = 0.53$ , the mixed equilibrium of Fig. 10 where there are no cognitive biases (i.e.  $\gamma = 1$ ).

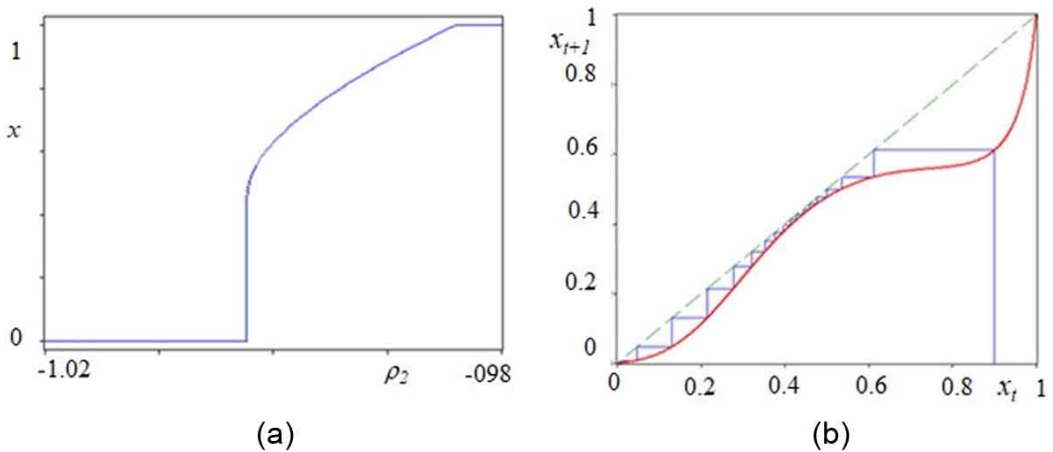
Thus, the cognitive bias that poses an excessive emphasis in wages of developing economies contributes to alter the location decision of the representative firm, even though neither a cost nor any other economic condition has changed. This proves how an improper perception and a superficial evaluation of cost-benefit in international operations could bring profit losses. Indeed, the biased



**Figure 15. Two interior equilibrium points. Parameters:**  $p = 1000, A_{L1} = 0.10, A_{L2} = 0.07, \rho_1 = -1, \rho_2 = -1, LP_1 = 0.12, LP_2 = 0.11, \beta_1 = 0.08, \beta_2 = -0.03, L_1 = 180, L_2 = 200, H_1 = 95, H_2 = 65, \alpha = 1, \omega = 3, w_1 = 15, w_2 = 8, w_3 = 45, w_4 = 35, \theta_1 = 0.6, \theta_2 = 2$



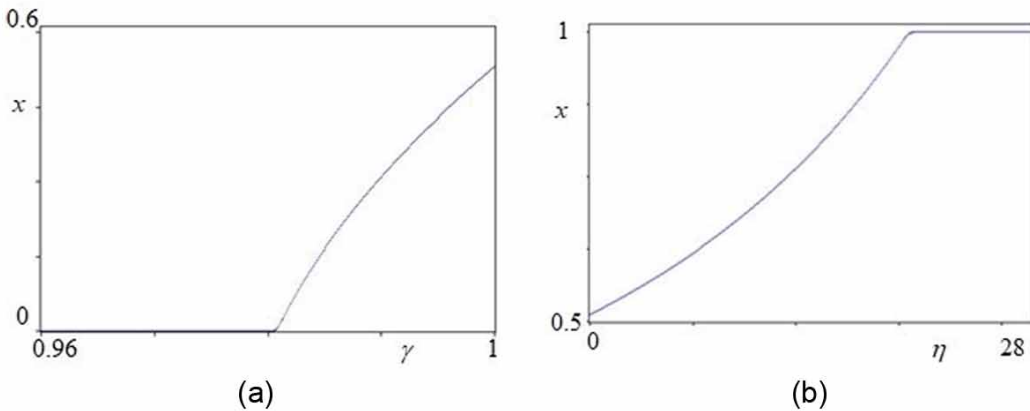
**Figure 16. Bifurcation diagram with the technology in developing country  $\rho_2$  used as bifurcation parameter (panel a). Phase diagram with  $\rho_2 = -1.003$  (panel b). All other parameters as in Fig. 15, and the initial condition  $x(0) = 0.9$**



firm' expected profit in country 2 is  $\pi_2^e(x)$  as given in (12), but the real profit earned is only  $\pi_2(x)$  in (8). As  $\gamma < 1$ , it follows that  $\pi_2^e(x) > \pi_2(x)$ : the choice is biased. The expected and the real profits coincide only when there is no cognitive bias,  $\gamma = 1$ . This is a generalization of the model described in Section 3.

Analogously, in Figure 18(b), starting again from the situation of Fig. 10 and gradually increasing the parameter  $\eta$  of the “made-in” effect, we assist to a growing reshoring of manufacturing activities,

Figure 17. Bifurcation diagram for wages' cognitive bias  $\gamma$  (panel a) and "made in" effect  $\eta$  (panel b). All other parameters being as in Fig. 10



and when  $\eta$  reaches the threshold value of 22 the entire production is reshored. In this case, the convenience to reshore is real because the firm knows that customers are willing to pay a surplus if a certain amount of the final product is manufactured in the country of origin. This surplus will be bigger as long as manufacturing activities are reshored in the home economy. The higher price increases the revenues and the expected profit  $\pi_1^e(x)$  in the home country, *ceteris paribus*.

## 6. CONCLUSION AND FURTHER POSSIBLE EXTENSIONS

A discrete-time adaptive mechanism has been proposed to describe the long run evolution of manufacturing location choices of a representative firm that, at each time step, can decide about offshoring or reshoring its production between a technologically developed home country, characterized by higher salaries, higher labor productivity and more skilled workers, and a developing country, characterized by lower salaries, lower labor productivity and lower R&D as well as less efficient infrastructures. Like in Radi et al. (2021) a profit-driven replicator dynamics has been employed to describe the strategic switches between the two production locations. However, the model proposed in this paper differs in the economic setup of the profit function because a constant elasticity of substitution (CES) production function, with skilled and unskilled labor force, is proposed to describe the aggregate production of the industry considered, along the line indicated by Acemoglu and Autor (2011), Autor and Dorn (2013). The influence of some important economic parameters and policies has been investigated by a trade-off between analytical and numerical methods, in order to reveal the circumstances under which a pure strategy equilibrium is reached, such that the whole production is offshored or reshored, and under what economic conditions a stable equilibrium of partial offshoring reveals to be optimal. Moreover, when several kinds of stable long run patterns coexist, so that a path dependence occurs (i.e. historical accidents matter) a characterization of such dependence has been given in terms of basins of attraction, bounded by unstable equilibria.

In particular, by properly tuning the parameters of the dynamic model, different scenarios are described. Despite a lower cost of labor in the developing country, the higher productivity of the workforce employed in the developed one completely offsets the cost convenience of cheaper salaries. This proves that in order to counteract the competition of low-wages economies it is not necessary to perform a race to the bottom of the salaries, but rather acting on the lever of developments and innovation to increase the attractiveness of a country. Other dynamic economic scenarios are simulated where the opportunity of exploiting greater advantages in terms of technological and R&D spillovers in

the developed country is an important driver that may lead to the final preference of the firm towards the total reshoring of activities.

Of course, situations are shown where low salaries together with acceptable productivity of labor force in the developing country contribute in favor of offshoring production.

In addition, the occurrence of cyclic location patterns of the MNE moving the opposite location choices are highlighted, through typical overshooting effect, that may even lead to chaotic location patterns.

Finally, the presence of some behavioral biases in the location decisions have been added as possible improvements of the stylized model. For example, the cognitive bias related with the fact that in advanced economies the production costs are mainly due to salaries because other costs (e.g. infrastructures, workers' training) are partially covered by government institutions (i.e. public goods), whereas in developing economies these factors should be considered as they reduce the productivity of workers. Moreover, on the demand side, consumers may exhibit a behavioral bias leading to purchasing decisions that are influenced by products' country of origin, so that they are willing to pay more if the products are manufactured in the developed country. Both these biases have been inserted in the model, even if their consequences have been only partially explored. Of course, they can be deeper investigated in the future thanks to the generality of the model proposed.

Other important aspects that may be worth to be considered in future extensions of the model proposed in this paper are related to the common perception that producing in countries where legislation is lenient, especially for environmental issues, could be more convenient. Moreover, the constant parameters that represent the workers' skillness may be endogenously determined in the model as proportional to production history in a given country, as workers' experience and skillness increases through learning by doing processes.

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