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REM RESEARCH IN ECONOMICS AND MATHEMATICS

Deindustrialization in the light of classical location theory

By

Armando J. G. Pires[1] and José Pedro Pontes[2]

Abstract: In this paper, we used a framework due VON THUNEN (1966) and Friedrich LIST (1841) where manufacturing development is regarded as a process of "refining" primary raw materials in order to yield "lighter", easier to carry products. If the artificial regulations which formerly kept industrial plants confined to core urban areas are abolished, then factories shift to rural areas in order to be close to the sources of farming raw materials, provided that the industrial transformation is sufficiently weight losing. However, the new productive sites for manufacturing will remain at a bounded distance from the Town, since they must bear the transport costs of shipping the output to the central meeting point where it must be transacted. Areas which are beyond this distance threshold are occupied by a traditional cottage economy, where goods are not carried to the Town but are rather produced for the household self-consumption. This framework also explains the observed fact that, within manufacturing, *resource based* branches are more centrally located in relation to core urban areas than other sectors.

Keywords: Deindustrialization; Land Rent; Location Theory; Von Thunen; Economic Development.

JEL Classification: O14, R11, R30

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Introduction

Looking at the geography of manufacturing activity in Europe in recent times, two remarks become easily noticed. Firstly, the industrial growth is concentrated neither in the European core, not in its periphery, but rather in regions with an *intermediate level* of accessibility. The three countries of the European Union where the rise of manufacturing valued added was higher between 2000 and 2012 were Poland, Slovakia and Lithuania, all of them exhibiting an intermediate degree of centrality, as measured inversely by the distance between their capitals and Brussels.

Secondly, new plants in *resource based* industries within manufacturing, such as the *processed food* sector, tend to have more central locations than the mean. In this paper, we try to assess in theoretical terms the process of industrial decentralization, which is usually coined as *deindustrialization*, in a way that is consistent with the two above described stylized facts.

Our approach to manufacturing is based upon the introduction of *milling* or *distilling* in VON THUNEN's (1966, in page 175) system of concentric rings. It is well known that, in this system, crops are located around a central Town following a decreasing order of the transport cost of the physical output yielded per unit of land. Since the industrial transformation of an agricultural raw material is a weight losing process, it makes profitable its cultivation at longer distances from the Town.

Following VON THUNEN, Friedrich LIST (1841, in page 141) regarded the increase of the transportability of agricultural (or mining) products through its "refining" as the natural path for the industrialization of remote and agrarian economies.

Starting with KRUGMAN (1991), the New Economic Geography strand of literature seemed to deal with the deindustrialization issue as it modeled explicitly a two region economy made up by two different sectors, agriculture and manufacturing, which work under opposite regimes. Furthermore, the original model dealt with the subject of the continuity in time of a situation where all manufacturing is concentrated in a region, the other one being specialized in agriculture. For that purpose, it finds out the conditions which ensure that no industrial firm in the cluster has an incentive to relocate to the agrarian region.

However, the idea that an agrarian economy may industrialize through the refining of raw materials produced by the primary sector cannot be accepted within KRUGMAN's (1991) framework because it presupposes that the agricultural product is lighter (it has zero transport cost) than the manufactured goods, which bear a positive transport cost.

By contrast, the attempt by FUJITA and KRUGMAN (1995) to integrate the New Economic Geography approach with VON THUNEN's (1966) land rent and location model is compatible with a resource based industrialization process because it presupposes that agricultural products also bear a positive transport cost. Starting with a total agglomeration of manufacturing, the two transport rates (of agricultural and manufactured goods) condition the decision of a firm to relocate in two opposite ways. Since agriculture is spread in space, high transport costs of food decrease the wage that a deviating firm has to pay and act therefore as a centrifugal force. By contrast, as manufacture is fully agglomerated (the so called

“monocentric pattern”), high transport costs of industrial goods increase the wage that must be supported by a firm deciding to leave the cluster and they operate as a centripetal force.

FUJITA and KRUGMAN (1995) establish that the interplay of these two opposing forces is also driven by the demand elasticity addressed to each differentiated industrial firm, which is finite by assumption because the manufacturing sector works in monopolistic competition. If instead the industrial goods were homogeneous and produced under perfect competition, the monocentric pattern would never be an equilibrium as a firm deviating from the cluster would attract enough customers to make its move profitable.

However, even with differentiated manufactured products, the “monocentric pattern” can be ruled out in principle through the assumption that the transport cost of manufactured goods is significantly lower than the transport cost of primary goods. This is equivalent to set a condition that the rate of weight losing in the industrial transformation of raw materials is high. Then, the “milling” and “distilling” plants will locate in equilibrium outside the initial main manufacturing agglomeration, which can only be sustained through artificial restrictions such as the imposition of a tariff on the imports of industrial goods by the Town dwellers.

Clearly, deindustrialization is the result of manufacturing growth in former remote agrarian areas. Old factories in central urbanized areas shut and are relocated to formerly rural region. Consequently, it can modeled through the VON THUNEN/LIST paradigm of viewing manufacturing as process of refining raw materials supplied by the primary sector in order to produce goods which are lighter and more transportable in space. This is precisely the scope of the analysis in this paper.

Some empirical evidence on new manufacturing location within the European Union

In the Table shown in the Appendix, we show for each of 26 countries of the European Union an inverse index of accessibility and the annual growth rate of the output in aggregate manufacturing and in two industry subsets.[3]

REMOTENESS or the inverse of country centrality is measured by the road distance (in $1000\ Kms$) between the country capital and Brussels. In order to account for internal distances in Belgium, this country was assigned the same distance as the neighboring Netherlands.

The variable MANUF is just the average annual growth rate (in %) of manufacturing value added in the country between years 2000 and 2012. The variable FOOD is the average growth rate of country value added in a subset of industries during the same time period which comprise "food, beverages and tobacco" and "textiles and clothing". The variable MACHINERY stands for similar data for another subset of manufacturing industries which is composed of "machinery and transport equipment" and "chemicals". The data for these three variables were found in the *World Development Indicators* issued by the World Bank.

The 26 EU countries were divided into three macro regions according to the $\frac{1}{3},\frac{2}{3}$ quantiles of REMOTENESS, which were respectively $1.1 \text{ and } 1.8$. These were the following.

1. A central region (CENTRE) which is composed of countries whose remoteness is included in the closed interval $[0,1.1]$. They form the set

$$\left\{\begin{array}{l}\text{Austria, Belgium, Czech Republic, Denmark, France,}\\ \text{Germany, Ireland, Netherlands, United Kingdom}\end{array}\right\}$$

2. A middle region (MIDDLE) which comprises the countries whose road distance to Brussels belongs to the closed interval $[1.1,1.8]$. They comprise the set

$$\{\text{Austria, Hungary, Italy, Lithuania, Poland, Slovakia, Slovenia, Spain, Sweden}\}$$

[3] Malta and Luxembourg are not considered because they are too small in population and geographical área. Croatia was discarded because it had no data on the structure of manufacturing output.

3. A peripheral region (PERIPHERY) which consists of the countries whose REMOTENESS is higher or equal to 1.8. It contains the following countries.

$$\{\text{Bulgaria,Cyprus, Estonia, Finland, Greece, Latvia, Lithuania, Portugal, Romania}\}$$

For each macro region, we calculated aggregate values of each variable by taking the simple arithmetic mean within each group. Table 1 shows the result of this geographic aggregation.

Table 1

Macro regions of EU	MANUF (1)	FOOD (2)	MACHINERY (3)	REMOTENESS
Centre (1)	1.6	1.5	3.6	0.6
Middle (2)	3.3	2.5	5.6	1.4
Periphery (3)	1.8	0.2	3.5	2.3

Looking at the mode of each variable, it is clear that manufacturing locates in countries with an intermediate centrality within the EU.

In order to differentiate the locational patterns of FOOD (or resource based products) and MACHINERY (or capital intensive industrial goods) within overall manufacturing, we assess the average distance to Brussels of each subsector within manufacturing. Formally, we define

$$\begin{aligned} &l_j \equiv \text{ average distance of the new industrial capacity} \\ &\text{(built between 2000 and 2012) in industrial sector } j=1,2,3 \text{ to Brussels.} \end{aligned} \tag{1}$$

The formal definition of l_j is the following weighted average.

$$l_j = \frac{\sum_{i=1}^{i=3} d_i r_{ij}}{\sum_{i=1}^{i=3} r_{ij}} \tag{2}$$

Where we define

$$\begin{aligned} &d_i \equiv \text{ average distance of a point within macro region } i=1,2,3 \text{ to Brussels.} \\ &r_{ij} \equiv \text{ average annual growth rate (in \%) of the value added} \\ &\text{of industrial sector } j=1,2,3 \text{ in macro region } i=1,2,3 \\ &\text{between years 2000 and 2012.} \end{aligned} \tag{3}$$

The computed average distance between the new production sites and the EU centre for manufacturing as a whole and its two subsectors are

$$\begin{aligned} l_1 &\approx 1.45 \\ l_2 &\approx 1.16 \\ l_3 &\approx 1.42 \end{aligned} \tag{4}$$

Two comments to the industrial locations shown in (4) are in order. Firstly, manufacturing as a whole tends to cluster in the countries endowed with an intermediate accessibility within the EU. Secondly, relatively capital intensive industrial sectors, such as machinery, tend to choose locations within the EU which are more remote than the productive sites selected by comparatively more resource based industries, such as the processed food industry.

This European trend of manufacturing relocation away from core areas towards regions endowed with an intermediate degree of accessibility or centrality can also be found at the intra-national level. For instance, TEIXEIRA (2006) noticed such a trend within Portugal in the period 1985-1998.

A spatial model of deindustrialization

The structure of the spatial economy

Location theory in the line of VON THUNEN (1966) provides us a fruitful way of considering the loss of manufacturing by formerly industrialized countries.

We presuppose in formal terms an economy where production is made with three production factors, labor, physical capital and land. We will use here the concept of *bid rent*, which is implicit in VON THUNEN (1926) and then defined by ALONSO (1964). *Bid rent* is the maximal rent per unit of land that the producer can afford to pay while keeping a constant level of profit.

The economy has two major parts, namely a *traditional sector* and a *modern sector* (see MURPHY et Al, 1989). In the former, a set of households or *cottages* produces a composite consumer good for self-consumption. Since there is no product specialization across producers and no transportation activity, we may write the bid rent as a parameter $\overline{\Upsilon}_t > 0$.

By contrast, in the *modern sector*, each producer specializes in a different kind of product for which the inputs are complements. Let the set of particular products generated in the modern sector of the economy be labeled by subscript $i = 1, 2, 3, \ldots$ Hence, the producer of good i makes one unit of output through expending c_i euros in labor and f_i euros in physical capital per unit of land. Furthermore, rather than be consumed locally, each product must be shipped to a central market, located in a Town, where it is sold under competitive conditions.

Then, the profit made by a producer i in the modern sector who is placed at a distance r from the central market is given by

$$\pi_i(r) = p_i x_i - c_i - f_i - t_i x_i r - R_i(r) \tag{5}$$

Where

$$\begin{aligned} &p_i \equiv \text{ competitive price of product } i \text{ at the central market.} \\ &x_i \equiv \text{ amount of output } i \text{ (in units of weight, tons)} \\ &\text{produced per unit of land (in } Km^2\text{).} \\ &t_i \equiv \text{ transport cost of product } i \text{ per unit of weight, per unit of distance.} \\ &R_i(r) \equiv \text{ Rent per unit of land paid by producer } i \\ &\text{at distance } r \text{ from the central market.} \end{aligned} \tag{6}$$

Since the market of each product works in perfect competition, each producer's profit becomes zero in the long run. Consequently, the bid rent by a market oriented producer i who

intends to keep a zero profit level in the long run and locates at a distance r from the central market is shown as

$$\Upsilon_i(r) = p_i x_i - c_i - f_i - t_i x_i r \tag{7}$$

For the sake of simplicity, we will presuppose that the following parameters do not vary among particular products.

$$c_i = c,\ t_i = t, \forall i$$

Consequently, the bid rent by producer i in (7) can be written as

$$\Upsilon_i(r) = p_i x_i - c - f_i - t x_i r,\ i = 1,2,3,... \tag{8}$$

We presuppose a space economy given by the set U , which is endowed with an Euclidian metric so that movement is feasible over all directions. We further assume that the transport rate per unit of weight per unit of distance, t , is the same across all directions. The "quality" of land (for instance, its "fertility" for a farming purpose) is everywhere the same.

The economy is made by two countries: a *central* and a *peripheral* country, which are labeled as C and P , respectively. Country C is made up by a Town and an encircling ring with radius b. Since the Town is just a "meeting point" for traders, we presuppose that its area is positive but arbitrarily small.

Country P is just the complement $U \setminus C$, i.e. the space that is occupied by the *central* country. In both countries, commercially oriented producers use the Town as the single central market where products are shipped to and transacted. Figure 1 depicts a possible landscape.

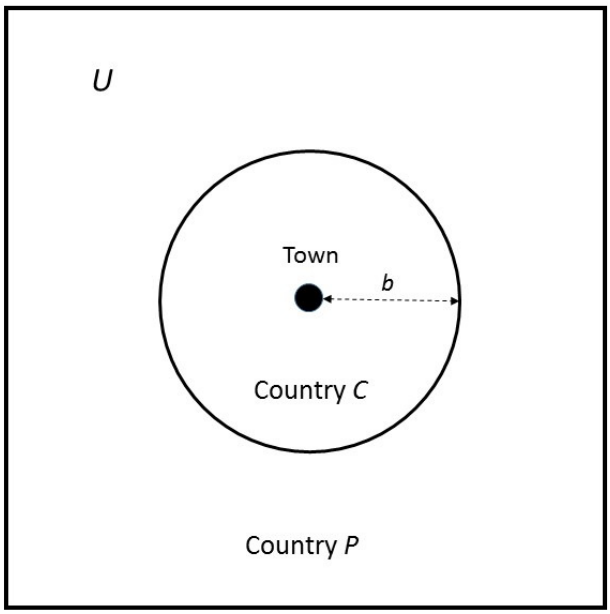

Figure 1 – Geographical setting of the economy

The location of manufacturing within Von Thunen's framework

Although VON THUNEN's model is usually adopted in order to explain crop location, it also contains a theory of industrial location. In his framework, manufacturing is viewed as being composed of two vertically related productive stages. The first stage is "agriculture" which consists in producing a raw material (for instance, a cereal) through the cultivation of land using labor. Then, in the second stage, the agricultural input is subjected to an industrial transformation or "refining" which causes a weight loss, thereby yielding a "lighter" and easier to carry manufactured good. Two examples of weight losing process are "distilling", where the cereal is converted into alcohol (see VON THUNEN, 1966, p. 175), and "milling", where the cereal is transformed into flour, which can be directly used to make bread (see LIST, p. 141).

In the beginning, it is presupposed that there exist "artificial regulations" that confine the "refining" stage to the Town. Industrial plants in the town use the cereal produced over the country side. Hence, there are two activities whose location is explained by the model.

In the modern sector of the economy, there is a single activity, namely "crop agriculture" which cultivates a raw material and ships it to the Town, where it is transformed into a "lighter" manufactured good (such as alcohol or flour). According to (8), we can write the bid rent function as

$$\Upsilon_a(r) = p_a x_a - c - f_a - t x_a r \tag{9}$$

In the traditional sector, industrial goods are produced to be self- consumed by the household, so that no transportation takes place. Consequently, the bid rent does not vary in space. And we have,

$$\Upsilon_t(r) = \overline{\Upsilon}_t \tag{10}$$

Since we have

$$\left|\Upsilon'_a(r)\right| = tx_a > \left|\Upsilon'_t(r)\right| = 0 \tag{11}$$

We can show the locations of "refining", crop agriculture and the traditional sector by means of Figure 2.

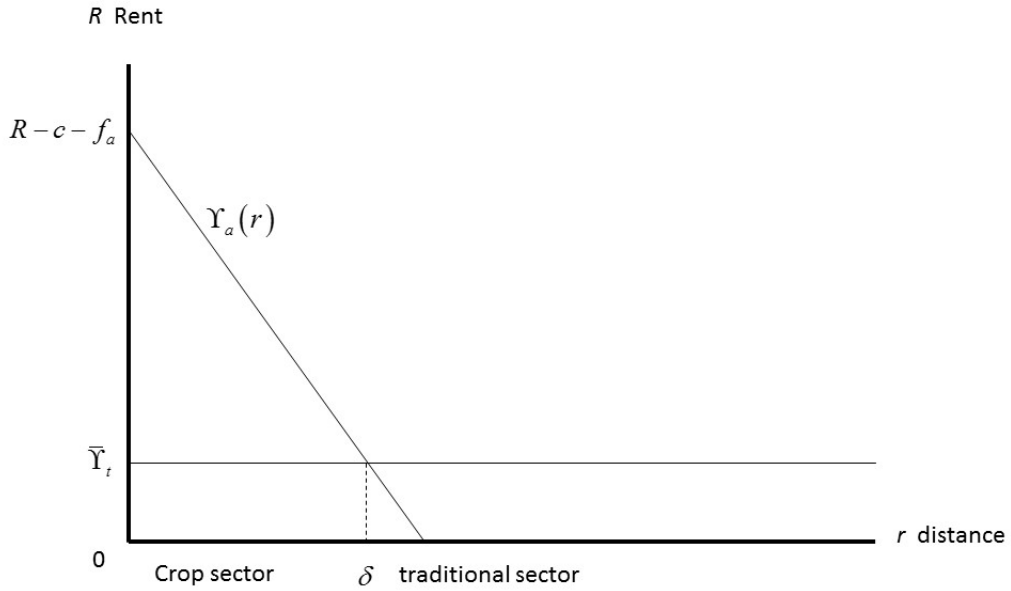

Figure 2. Productive locations with refining confined to the Town

We can summarize Figure 2 by saying that factories locate only in the Town which is surrounded by a farming ring producing the raw materials used by the urban manufacturing. Beyond distance threshold δ, to export the cereal to the Town ceases to be profitable on account of prohibitive transport costs and farmers start to self- produce the refined goods they need in the context of a traditional economy.

We presuppose now that, in a given moment of time, the artificial regulations which constrained factories to be located in the town are ended. Consequently, farmers have now the option to refine the cereal locally, thus exporting a lighter, easier to carry final product. For that purpose, they must support an investment cost per unit of area (a "mill" or "distillery"). Their bid rent curve becomes

$$\Upsilon_m(r) = p_m x_m - c - f_m - tx_m r \tag{12}$$

Where the relation with the bid rent function of commercial agriculture in (9) is given by the following inequalities.

$$\begin{aligned} x_m &< x_a \\ f_m &> f_a \end{aligned} \tag{13}$$

Since prices of the raw material and the manufactured are competitive, the market exchange relationship of the two products should equal the rate of transformation in production so that the following equality holds,

$$\frac{p_m}{p_a} = \frac{x_a}{x_m} \tag{14}$$

Consequently, total revenues R per unit of land are the same for the crop farmer and the industrialist.

$$R = p_a x_a = p_m x_m \tag{15}$$

We can write the bid rent functions of the three productive activities in the economy from (9), (10), (12) and (15), in the following way.

$$\begin{aligned} &\text{Agriculture - } \Upsilon_a(r) = R - c - f_a - t x_a r \\ &\text{Manufacturing - } \Upsilon_m(r) = R - c - f_m - t x_m r \\ &\text{Traditional sector - } \Upsilon_t(r) = \overline{\Upsilon}_t, \forall r \end{aligned} \tag{16}$$

The order of the bid rent slopes (in absolute value), which are equivalent to the transport cost of the physical output (in weight units) per unit of area is,

$$\left|\Upsilon'_a(r)\right| = x_a t > \left|\Upsilon'_m(r)\right| = x_m t > \left|\Upsilon'_t(r)\right| = 0 \tag{17}$$

Hence, the productive geography of the can be plotted in Figure 3.

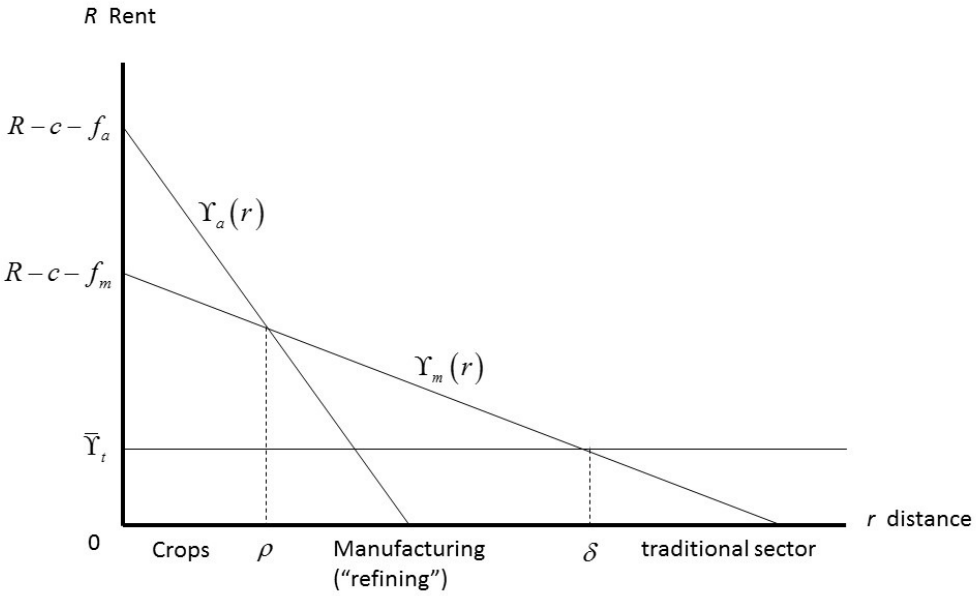

Figure 3. Productive pattern with freely located industrial plants

Figure 3 may lead to two different types of understanding. In **static terms**, starting from the central Town and considering regions at increasing g distances, we see that there will be manufacturing plants in the Town, which is surrounded up to the distance threshold ρ by an agricultural ring. The farmers in this ring supply the urban factories with agricultural raw materials. Beyond distance ρ, transport costs become too high for the export of raw materials to the Town. Hence, in distances r such as $\rho < r < \delta$, farmers resort to refining themselves the raw materials, thereby producing "lighter" manufactured goods which they send to the central Town market. Further than distance δ, even the export of refined products to Town becomes unprofitable and the economy switches to a traditional pattern where each household produces all the goods it needs for its own consumption.

Instead in **dynamic terms**, we can assess the economic impact of ending the artificial regulations that confined manufacturing to the central Town through the comparison of Figure 3 with Figure 2. Then, it is clear that the liberalization of industrial location leads to a decrease of manufacturing activity in the Town and its emergence in middle regions which are neither too close not too far away from it. Since the growth of refining units in formerly rural areas leads to an increase in product transportability, we also see that the traditional cottage economy becomes more remote and holds within a much smaller domain.

We now take into account the political aspects of industrialization, namely the fact that the border between the central and peripheral countries is located at a distance b from the central Town (see Figure 1). Clearly, the deindustrialization of a large central country will be less intense than the one prevailing in a small one, since the new industrial plants emerging in the countryside will likely remain within the country territory. Bearing in mind the economic frontier point ρ in Figure 3, this condition can be written approximately as

$$b > \rho \tag{18}$$

The distance ρ to the Town where land switches from a farming to a manufacturing use is determined by the equality of the two bid rents curves.

$$\begin{aligned} &\Upsilon_a(\rho) = \Upsilon_k(\rho) \\ &R - c - f_a - tx_a\rho = R - c - f_k - tx_k\rho \end{aligned} \tag{19}$$

The solution of (19) is

$$\rho = \frac{f_m - f_a}{(x_a - x_m)t} \tag{20}$$

We define

$$\theta \equiv \frac{x_a - x_m}{f_m - f_a} \tag{21}$$

The numerator of (21) is the amount of weight loss following from the refining of the primary input (a cereal), while the denominator expresses the increase in capital expenditure (for instance, a new "mill" or "distillery") which is necessary to industrial transformation. Parameter θ is akin to the concept of autonomous technical progress or total factor productivity as it was put forward by SOLOW (1957).

By substituting (21) in (20), the economic frontier between agriculture and manufacturing becomes

$$\rho = \frac{1}{\theta t} \tag{22}$$

By inserting (22) in (18), the condition for the central country to avoid manufacturing loss after the ending of artificial regulations which formerly constrained factories to be sited in the Town can be written as

$$b\theta t > 1 \tag{23}$$

Condition (23) tells us that the location of manufacturing in the central country can be achieved through three different policy means.

1. Moving out the borders of the country, i.e., increasing b. A recent instance is the enlargement of the European Union to Central and Eastern European countries since 2004 which allowed German manufacturing to keep on growing at a significant rate.
2. Increasing the overall productivity of the industrial process θ as expressed by the amount of "refining" the raw materials for a given increase in the capital input. Technical progress allows industrial firms to afford to pay the higher land rents which prevail close to the Town in the central country.
3. Increase the transport rate of goods from the production site to the Town, thereby stimulating more central locations for the plants. This could be achieved through the imposition of a tariff at the border separating the central and peripheral countries. We should be aware that in this instance trade protection has nothing to do with the so called "infant industry argument", as here production takes place under constant returns and competitive market conditions. In the reality, such a policy cannot take place obviously **within** the European market nowadays but it can arise through an increase of the common European tariffs on imports from outside the EU, which are nowadays rather low (about 3% for non- agricultural products). This rise of common tariffs would allow some "trade diversion" (VINER, 1950) which would benefit particularly the more disadvantaged countries within the EU.

Furthermore, condition (23) tells us that the three policy instruments to prevent deindustrialization (or to foster industrial growth) are related among themselves in a **multiplicative way**, so that they represent substitute strategies to promote industrial growth.

Evolution of the manufacturing structure of the central country

Let us assume that, instead of "agriculture" and "manufacturing", the two sectors , j and k whose relationship is shown by inequalities (13), are given the meaning of "resource based" manufacturing (such as "processed food") and "capital intensive" manufacturing (such as "machinery and transport equipment"). Then our theoretical explanation in Figure 2 will involve the prediction that the central country will become relatively more specialized in the former type of manufacturing activities while the peripheral country will be more biased towards the latter type of manufacturing. Indeed, this idea is confirmed by empirical evidence.

Concluding remarks

In this paper, we used a framework due to VON THUNEN (1966) and Friedrich LIST (1841) where manufacturing development is regarded as a weight losing process of refining primary raw materials in order to yield “lighter”, easier to carry products. If the artificial regulations which kept industrial plants confined to core urban areas in the beginning are abolished, and the refining rate is high enough, then factories shift to formerly rural areas in order to be close to the sources of raw materials. However, the new productive sites for manufacturing will remain at a bounded distance from the Town, since they must bear the transport costs of shipping the output to the central market where it must be transacted. Areas which are beyond this distance threshold are occupied by a traditional cottage economy, where goods are not carried to the Town but are rather produced for the household self-consumption.

This framework also explains the observed fact that, within manufacturing, *resource based* branches are more centrally located in relation to core urban areas than other sectors.

The degree of deindustrialization can be controlled through three policy instruments. The first one consists in moving out the central country borders by means of regional integration agreements. The second one is technological progress leading to an increase of the “refining rates” for given amounts of the used capital inputs. The increased weight loss in production enables industrial firms to save on transport costs and allows them thereby to pay the higher land rents prevailing in the central country. Lastly, the increase of transport costs stimulates plants to choose locations in the proximity of the core market.

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Appendix - Table with data on accessibility and industrial growth rates for 26 countries in the European Union during the time period 2000 - 2012

EU Countries	REMOTENESS	% MANUF	% FOOD	% MACHINERY
Austria	1.1	2.1	1.5	3.1
Belgium	0.2	0.9	1.4	1.9
Bulgaria	2.1	4.6	4.4	4.6
Cyprus	3.7	–2.8	–3.4	1.6
Czech Rep.	0.9	5.8	2.4	7.7
Denmark	0.9	0.2	–1.6	4.3
Estonia	2.2	4.5	0.2	7.7
Finland	2.0	0.4	3.0	–1.8
France	0.3	0.7	2.5	4.3
Germany	0.8	1.4	–0.4	3.1
Greece	2.8	–1.7	–1.7	–3.5
Hungary	1.4	2.5	–1.7	5.3
Ireland	1.0	3.2	6.4	3.8
Italy	1.5	–0.7	–1.1	0.8
Latvia	2.0	2.1	–2.1	5.2
Lithuania	1.8	6.0	2.9	8.4
Netherlands	0.2	0.7	1.1	3.0
Poland	1.3	7.3	12.7	9.8
Portugal	2.0	–0.6	–0.9	–0.2
Romania	2.2	3.5	–0.9	9.3
Slovakia	1.2	8.3	7.0	12.2
Slovenia	1.2	2.3	–1.8	5.1
Spain	1.6	–0.5	0.6	0.6
Sweden	1.6	2.1	2.1	5.3
United Kingdom	0.4	–0.6	0.3	1.1