

## A SIMPLE DYNAMIC MODEL OF UNEVEN DEVELOPMENT AND OVERTAKING\*

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This paper extends the Brezis *et al.* (1993) Ricardian leapfrogging model by introducing geographically mobile capital and allowing for a wider variety of development patterns. In a two-region economy, localised learning-by-doing causes specialisation and uneven development. Technological change reverses the existing development pattern if the new technology locates in the low-wage region. However, the development pattern may also be reinforced if spillovers between the old and the new technology make the leading region a more attractive location. Capital flows are explicitly analysed and it is furthermore shown that inter-regional transfers may reduce the chance of take-off.

At the end of the eighteenth century, the Dutch enjoyed the highest consumption per capita on the European continent, quite different from the meagre subsistence income of Belgium's impoverished peasantry. However, during the industrial revolution new technologies started locating in Belgium, attracted by its low wages (Mokyr, 1976). By 1850, Belgium had become the most industrialised nation on the continent, leaving the Netherlands lagging behind.

Technological change does not always benefit backward regions though. Advanced regions may continue to attract new industries if technological spillovers are sufficiently strong to compensate for higher wages. Denmark, for instance, building on its strength in fermentation techniques and beer brewing, became successful in biotechnology; and Japan, using its expertise in optics, moved from cameras to photocopiers and fax machines (Porter, 1990). More recently, Silicon Valley, known for its semi-conductor industry, became the focal point of internet start-ups; in spite of its high wages, the Valley provided a steady stream of professionals with the right skills.

This paper proposes a two-region model of uneven development, in which technological change either benefits the backward or the advanced region. If spillovers between the old and the new technology are weak, the new industry locates where wages are low, giving the backward region a chance to take off and leapfrog. If spillovers are strong enough, the advanced region adopts the new technology, and reinforces its dominant position.

Our model builds on previous work by Brezis *et al.* (1993). They develop a dynamic Ricardian trade model where localised learning externalities lead the economy to diverge into a rich manufacturing region and a poor agricultural

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region. When then a new technology is introduced, it locates in the low-wage region. As the new technology's productivity increases over time, the lagging region overtakes the leading region.

Since Brezis *et al.* (1993) limit their analysis to the case without spillovers, technological change always benefits the poorer region.<sup>1</sup> Our examples of Denmark, Japan and Silicon Valley suggest this is only part of the story. By allowing for spillovers between a region's expertise and the new technology, we encompass this richer set of possibilities. More specifically, if spillovers in the advanced region are strong, the new industry locates in the high-wage region. Though this mechanism has been pointed out before by Desmet (2000), the complexities of expectations in that particular set-up do not allow us to study the role of capital or to use the model for policy analysis. In a different context, the industrial organisation literature has also explored the conditions for leapfrogging. For instance, Motta *et al.* (1997) find that, with vertical product differentiation, free trade may either reinforce or reverse quality leadership.

We further depart from the Ricardian model of Brezis *et al.* (1993) by focusing on a Heckscher–Ohlin framework with mobile capital. This is important for a number of reasons. First, given its central role in growth and development, we want to see whether including capital affects our results. The standard Heckscher–Ohlin model would suggest it does: because of the tendency towards factor price equalisation, uneven development should disappear, or at least be mitigated. However, in the presence of capital mobility and localised externalities, this is not the case: the main conclusions from the Ricardian model go through and, instead of income convergence, we obtain income divergence. Second, our model allows us to study capital flows. In line with the results of Brezis and Tsiddon (1998), we find that capital flows to the region with the highest degree of technological progress. In the case of overtaking, this implies that the poor region starts attracting capital from the rich region well before the actual leapfrogging occurs, a finding consistent with the empirical evidence.

The simplicity of our model makes it an appropriate tool for policy analysis. In particular, we are interested in understanding the effect of inter-regional transfers on uneven development. While certain kinds of transfers – such as investment subsidies – may improve the lagging region's sort, other transfers – such as unemployment benefits or public employment – may contribute to the backward region's persistent underdevelopment. Although these latter transfers reduce inequality in a static sense, they diminish the likelihood of the backward region taking off. By raising wages without improving productivity, the lagging region finds it harder to attract new industries.

Using Italian regional data, we find evidence consistent with our theoretical predictions. Transfers to the Mezzogiorno in the form of unemployment benefits and public employment started an upward trend at the beginning of the 1970s. This became translated in to upward pressure on wages and a loss of

<sup>1</sup> Even though not formalising the argument, Brezis *et al.* (1993) hint that spillovers would change their results; indeed, they claim that, for leapfrogging to occur, 'experience in the old technology should not be too useful in the new technology' (p. 1218).

competitiveness, as reflected by the continuing relative increase of unit labour costs in the South. As a consequence, the Mezzogiorno became a less attractive place for new investments and technologies. This is borne out by the data on relative labour productivity: after increasing from 0.64 in 1960 to 0.80 in 1975, labour productivity in the South relative to the North has since then stagnated.

The remainder of this paper is organised as follows: Section 1 describes the set-up of the model and illustrates the process of uneven development; Section 2 introduces technological change, and shows how the development pattern is reinforced or reversed; Section 3 analyses the impact of inter-regional transfers; and Section 4 concludes.

## 1 Uneven Development

### 1.1 A Static Model

The basic structure of the model is a Heckscher–Ohlin extension of the Ricardian framework in Brezis *et al.* (1993). Consider two regions: East and West. For notational convenience, variables referring to the West are starred (\*). Each region is endowed with one unit of labour, and each region also owns one unit of capital.<sup>2</sup> Capital is geographically mobile, whereas labour is not. The physical location of capital – though not its ownership – is thus determined by the condition that returns to capital must equalise across regions. Assuming capital mobility seems appropriate. Although the traditional focus of the growth and development literature has been on domestic capital accumulation, the growing importance of foreign investment has slowly been changing this emphasis (Lucas, 1990; Rodríguez Clare, 1996; Fafchamps, 1997; Brezis and Tsiddon, 1998). Capital mobility is even greater when considering regions within countries, as witnessed, for instance, by the similarity in interest rates between US states (Barro *et al.*, 1995).

There are two sectors, food and manufacturing. The aggregate production functions of food in the East and the West are

$$Q_F = K_F^\alpha L_F^{1-\alpha} \quad (1)$$

and

$$Q_F^* = K_F^{*\alpha} L_F^{*(1-\alpha)}. \quad (2)$$

Whereas both regions use identical food technologies, manufacturing production is subject to region-specific learning-by-doing externalities,<sup>3</sup> so that the aggregate output of manufactured goods at time  $t$  can be written as

<sup>2</sup> Given that factor ownership is identical across regions, it may seem inappropriate to call this a Heckscher–Ohlin model just because we include capital. However, the main results do not depend on identical factor ownership; in the presence of capital mobility and localised externalities, factor ownership is irrelevant for the pattern of specialisation. Assuming no regional differences in factor ownership sharpens the analysis, though, by ensuring that initially both regions have similar income per capita levels.

<sup>3</sup> The effect of localised learning-by-doing on comparative advantage and growth has been studied, among others, by Bardhan (1970), Ethier (1982), Krugman (1987), Lucas (1988) and Young (1991).

$$Q_M(t) = A[E(t)]K_M^\beta L_M^{1-\beta} \quad (3)$$

and

$$Q_M^*(t) = A[E^*(t)]K_M^{\beta} L_M^{*(1-\beta)} \quad (4)$$

where a region's productivity depends on both direct experience producing manufactures and spillovers from other technologies:

$$E(t) = \int_0^t Q_M(s)ds + S(t) \quad (5)$$

$$E^*(t) = \int_0^t Q_M^*(s)ds + S^*(t). \quad (6)$$

Since spillovers will only matter once a new technology is introduced, assume for the moment that  $S = S^* = 0$ . The manufacturing learning curve is increasing and concave. Without any experience, productivity is  $\underline{A}$ ; as a region learns how to use the technology,  $A$  rises; eventually, learning peters out and productivity tends asymptotically to  $\bar{A}$ . Although, in its original formulation, learning-by-doing was defined as a function of cumulative investment (Arrow, 1962), rather than of cumulative production, there exists substantial empirical support justifying our choice.<sup>4</sup> We furthermore assume that manufacturing is relatively capital-intensive, so that  $\beta > \alpha$ .<sup>5</sup>

Consumers' preferences are Cobb–Douglas; they spend a fraction  $\mu$  of their income on manufactures and the rest on food. After normalising the food price to 1, we can derive the inverse demand function of manufactures relative to food:

$$p_M = \frac{\mu}{1 - \mu} \frac{Q_F + Q_F^*}{Q_M + Q_M^*}. \quad (7)$$

There are no savings. This may seem odd, given the central role of savings and capital accumulation in growth and development. However, the focus of this paper is on *relative* development, rather than on growth. In that respect, introducing savings would not affect the results in any substantial way. We will briefly return to this issue at the end of this section.

We first analyse the static free trade equilibrium, assuming manufacturing productivity is greater in the West than in the East:

$$A(E^*) > A(E). \quad (8)$$

Though this is essentially a Heckscher–Ohlin model, the mobility of capital, combined with localised externalities, makes the economy behave like a Ricardian trade model. Comparative advantage is determined by technological differences

<sup>4</sup> See Young (1991) for references.

<sup>5</sup> This assumption is irrelevant for most results; it will only play a (marginal) role in the analysis of Case 2 in Section 3.

and at least one region is fully specialised.<sup>6</sup> If consumers spend a large enough fraction of their income on manufactures, the West only produces manufactured goods. Whether the East then continues to produce both goods depends on the productivity advantage of the West. If the West's advantage is sufficiently large, it is able to satisfy all of the economy's demand for manufactures; if not, the East continues to produce part of its manufacturing consumption. These insights are summarised in Proposition 1.

**PROPOSITION 1** *If capital is mobile and the West has a productivity advantage in manufacturing, then*

- (a) *at least one of the two regions is fully specialised*
- (b) *comparative advantage is determined by technological differences*
- (c) *the West is fully specialised in manufacturing if*

$$\mu \geq \frac{1 - \alpha}{2 - \alpha - \beta} \quad (9)$$

- (d) *if the West is fully specialised in manufacturing, the East produces only food if*

$$\frac{A(E^*)}{A(E)} \geq \left( \frac{\mu}{1 - \mu} \frac{1 - \beta}{1 - \alpha} \right)^{1 - \beta}. \quad (10)$$

*Proof*

- (a) To show that (at least) one of the two regions is fully specialised, assume the contrary. Because of capital mobility, returns to capital equalise across regions and sectors. Equal returns to capital in food imply equal wages in the East and the West; however, equal returns to capital in manufacturing imply higher wages in the West than in the East (since  $A(E^*) > A(E)$ ). This violates the condition that wages must equalise across sectors in each region, so that (at least) one region must be fully specialised.
- (b) To show that the West has a comparative advantage in manufacturing, assume the contrary and focus on the case where the East specialises in manufacturing and the West produces both goods.<sup>7</sup> Since returns to capital equalise across regions, wages in the West must be higher than in the East (given that  $A(E^*) > A(E)$ ). However, since food technologies are identical, Eastern workers can earn these higher Western wages (without violating the capital mobility condition) by switching to food production. This

<sup>6</sup> As mentioned in footnote 2, this result would go through if factor ownership were to differ across regions.

<sup>7</sup> This is, of course, not the only case consistent with the East having comparative advantage in manufacturing. However, the other cases can be dealt with analogously and are left to the reader.

contradicts the above assumption; the West therefore has a comparative advantage in manufacturing.

(c) See Appendix B.

(d) See Appendix B.

For the remainder of this paper, we assume that (9) holds. If this condition were not satisfied, both regions would produce food. Since food technologies are identical in the East and in the West, capital mobility would lead returns to capital and wages to equalise across regions. In that case, we would never have uneven development.

### 1.2. *Introducing Dynamics*

Introducing dynamics in the model allows us to study how specialisation and growth patterns evolve over time. Assume that, at time  $t = 0$ , productivity in the East is at its lower bound, whereas in the West it is slightly higher:

$$A[E(0)] = \underline{A} \quad (11)$$

$$A[E^*(0)] = \underline{A} + \epsilon. \quad (12)$$

If the difference in manufacturing productivity is small enough, i.e. if (10) does not hold, the economy is initially partially specialised. In that case, returns to capital and wages in the East and the West are

$$r = p_M \beta A(E) \left( \frac{L_M}{K_M} \right)^{1-\beta} = \alpha \left( \frac{L_F}{K_F} \right)^{1-\alpha} = r^* = p_M \beta A(E^*) \left( \frac{1}{K^*} \right)^{1-\beta} \quad (13)$$

$$w = p_M (1 - \beta) A(E) \left( \frac{K_M}{L_M} \right)^\beta = (1 - \alpha) \left( \frac{K_F}{L_F} \right)^\alpha \quad (14)$$

$$w^* = p_M (1 - \beta) A(E^*) (K^*)^\beta. \quad (15)$$

Wages in the West relative to the East are therefore

$$\frac{w^*}{w} = \left[ \frac{A(E^*)}{A(E)} \right]^{\frac{1}{1-\beta}} \quad (16)$$

whereas total income per capita of the West relative to the East can be written as<sup>8</sup>

<sup>8</sup> Income in a given region, say, the East, is the sum of wages in the East and earnings from capital owned by the East, including if part of that capital is located in the West. Since each region has one unit of labour and owns one unit of capital, income per capita is  $w + r$  in the East and  $w^* + r^*$  in the West. To avoid any confusion, note furthermore that in any equation the variables  $K^*$ ,  $K_F$  and  $K_M$  refer to the capital's physical location, and not to its ownership.

$$\frac{w^* + r^*}{w + r} = \frac{A(E^*)^{\frac{1}{1-\beta}}[(1-\beta)K^* + \beta]}{A(E)^{\frac{1}{1-\beta}}(1-\beta)K^* + A(E^*)^{\frac{1}{1-\beta}}\beta} \tag{17}$$

Given the small difference in manufacturing productivity, wages are initially similar in the two regions. Since, moreover, each region owns half of the economy’s perfectly mobile capital stock, capital earnings are identical in East and West. Both regions are therefore at comparable initial income per capita levels, with the West having only a slight advantage.

Over time, the West’s specialisation in manufacturing allows it to accumulate manufacturing experience faster than the East. We assume this leads to a progressive increase in the West’s relative productivity:

$$\frac{A[\dot{E}^*(t)]}{A[E^*(t)]} > \frac{A[\dot{E}(t)]}{A[E(t)]} \text{ for all finite } t. \tag{18}$$

Although the exact conditions required for (7) to hold depend on the specific functional form of the learning curve, it is easy to see that, at least initially, (7) is satisfied. Indeed, since  $A[E^*(0)] \approx A[E(0)]$ , the denominators in (18) are approximately the same; given that, moreover,  $Q_M^*(0) > Q_M(0)$ , it follows that  $A[E^*(0)] > A[E(0)]$ , so that (18) holds. As the relative manufacturing advantage of the West increases, the East becomes more and more specialised in food and, at some point, it stops producing manufactured goods altogether.<sup>9</sup>

As long as the East is not fully specialised, the West attracts capital from the East (Figure 1).

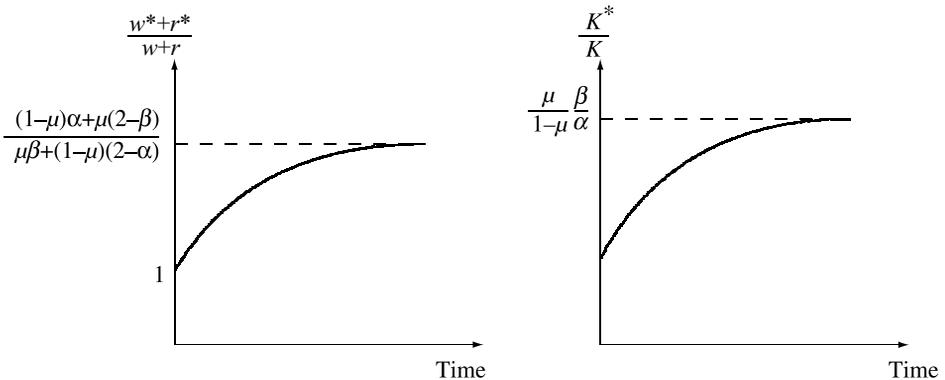


Fig. 1. Relative Income Per Capita and Relative Capital Stock Location

<sup>9</sup> From then onwards, it is obvious that (18) holds, since  $A[\dot{E}(t)] = 0$ .

**PROPOSITION 2** *As manufacturing productivity increases more rapidly in the West than in the East, capital flows from East to West until the East becomes fully specialised, at which point capital flows cease.*

*Proof* Start off in equilibrium with equal returns to capital across regions and sectors:

$$r^* = p_M \beta A(E^*) (1/K^*)^{1-\beta} = r = p_M \beta A(E) (L_M/K_M)^{1-\beta} = \alpha (L_F/K_F)^{1-\alpha}.$$

Now assume the West's relative productivity advantage grows (condition (18)). If the allocation of capital and labour were not to change, then

- 1 food production would remain the same, and
- 2 manufacturing production would increase proportionally by less than the increase in  $A(E^*)$ , but by more than the increase in  $A(E)$ .

Given Cobb–Douglas preferences, the price of manufactured goods would thus decrease proportionally by less than the increase in  $A(E^*)$ , but by more than the increase in  $A(E)$ . Returns to capital would therefore increase in the West, decrease in manufacturing in the East, and remain stable in food in the East. It thus follows that capital will flow from East to West. This capital movement ceases once both regions are fully specialised. In that case, the manufacturing price would decrease in the same proportion as the increase in  $A(E^*)$ , thus leaving the returns to capital unchanged. QED

This result is consistent with the findings of Brezis and Tsiddon (1998), who study the relation between capital flows and economic growth in a one-sector OLG model.

At the same time, the economy moves into a process of uneven development. Whereas capital income remains equal in both regions, the widening productivity gap, combined with capital inflows into the West, leads to diverging wages, as can be seen from (16).<sup>10</sup> Income per capita therefore grows faster in the West than in the East (Figure 1). This can be shown more directly by looking at (17): as the West's manufacturing productivity rises relative to the East's, and as capital flows from East to West (thus increasing  $K^*$ ), the West's relative per capita income increases. This process continues until the East stops producing manufactured goods.

Once the economy is fully specialised, the relative manufacturing price has become

$$p_M = \frac{\mu}{1 - \mu} \frac{K^\alpha}{A(E^*) K^{*\beta}}. \quad (19)$$

Since rental prices equalise across regions, the capital stock in the West relative to the East must then be

$$\frac{K^*}{K} = \frac{\mu}{1 - \mu} \frac{\beta}{\alpha}. \quad (20)$$

In that case, relative wages and relative total income per capita can easily be shown to be

<sup>10</sup> Though only relative productivity shows up explicitly in (16), the increasing capital–labour ratio in the West contributes to the widening wage gap.

$$\frac{w^*}{w} = \frac{\mu}{1 - \mu} \frac{1 - \beta}{1 - \alpha} \quad (21)$$

and

$$\frac{w^* + r^*}{w + r} = \frac{(1 - \mu)\alpha + \mu(2 - \beta)}{\mu\beta + (1 - \mu)(2 - \alpha)}. \quad (22)$$

As can be noted from (21) and (22), once regions have become fully specialised, productivity growth in the West does not further increase its relative income. Cobb–Douglas preferences are such that the gain in productivity is exactly offset by the decline in the terms of trade.

We have, therefore, shown that regions starting off at comparable levels of income may diverge over time. This result is similar to the one in Krugman (1981) and Brezis *et al.* (1993). In contrast to the factor price equalisation result familiar from the standard Heckscher–Ohlin model, capital mobility in the presence of localised externalities leads to income divergence. Under these assumptions, therefore, the Heckscher–Ohlin and the Ricardian models yield similar predictions. This is a potentially important insight in the light of the rising interest in economic geography, where localised externalities and factor mobility are standard assumptions.

Before concluding this section, it is worth considering how the results might change if we were to introduce savings and capital accumulation. The simplest way of doing so is to follow Solow (1956) and Lucas (1993) by supposing that the savings rate is constant and that capital accumulation is limited by depreciation. Given that the West starts off with a slightly higher income level, its total savings are greater, thus leading to more capital accumulation relative to the East. Compared to the model without savings, not only wages diverge but also per capita earnings from capital. The main message, therefore, does not change: starting off at similar levels of income, the West ends up at a higher level than the East.

## 2. Technological Change

Assume the economy is fully specialised and learning in the West has been exhausted, so that its manufacturing productivity is  $\bar{A}$ .<sup>11</sup> At time  $t'$ , we exogenously introduce a new technology  $A'$ . By analogy with the old technology, the learning curve of the new technology is increasing and concave. Without any experience, productivity is  $\underline{A}'$ ; with learning, productivity goes up, and tends asymptotically to  $A'$ . As illustrated in Figure 2, the new technology  $A'$  is 'superior' to the previous one: for any level of experience,  $A' > A$ .

This type of innovation can take on two different forms. On the one hand, it may refer to the production of an identical manufactured good, using a different technology. An example of this would be the introduction of the method of continuous casting in steel production at the end of the 1960s. On the other hand,

<sup>11</sup> Strictly speaking,  $\bar{A}$  is only reached asymptotically, and not in finite time. However, this assumption enhances tractability since it implies that productivity does not change any more with time.

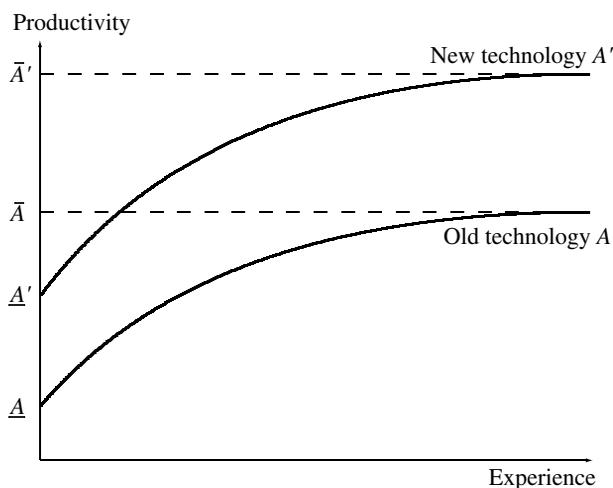


Fig. 2. *Old and New Manufacturing Technology*

it could also be a new industry which produces a perfect substitute for the original manufactured good. The rise of composite materials, for instance, has been replacing steel in many of its applications.<sup>12</sup>

Although low wages tend to attract the new industry to the East, learning spillovers from the original manufacturing technology may give the West an advantage in adopting the new technology.<sup>13</sup> Learning spillovers may differ in degree. If spillovers are complete, having accumulated experience with the old technology is equivalent to having had the same amount of experience with the new technology, so that  $A'[S^*(t')] = \bar{A}$ ; if spillovers are non-existent,  $A'[S^*(t')] = \underline{A}'$ . In general, spillovers in the West will be somewhere in between those two extremes. Before continuing, note that the East does not benefit from spillovers, given that its entire labour force is employed in food; its initial productivity in the new technology is therefore at its lower bound  $\underline{A}'$ .

To study the adoption of the new technology and the subsequent dynamics, we distinguish between three cases:

*Case 1: Reversal of development pattern*

$$A'[S^*(t')] \leq \bar{A} \quad \text{and} \quad \frac{\bar{A}}{\underline{A}'} < \left( \frac{\mu}{1-\mu} \frac{1-\beta}{1-\alpha} \right)^{1-\beta}.$$

If  $A'[S^*(t')] \leq \bar{A}$ , workers in the West do not have any incentive to adopt the new technology, because their accumulated experience with the old technology gives them a higher productivity; the West therefore remains locked into the old

<sup>12</sup> Since perfect substitutes are indistinguishable in the consumer's utility function, and there is thus a unique manufacturing price, the two interpretations are interchangeable, and do not make any difference for the theoretical analysis.

<sup>13</sup> Learning spillovers between sectors (or technologies) have been analysed in a theoretical framework by, for instance, Boldrin and Scheinkman (1988). Empirical evidence can be found in Jaffe *et al.* (1993) and Glaeser *et al.* (1992).

technology due to weak spillovers. However, the low-paid workers in the East do find the new technology attractive if, by analogy with (10),<sup>14</sup>

$$\frac{\bar{A}}{\underline{A}'} < \left( \frac{\mu}{1-\mu} \frac{1-\beta}{1-\alpha} \right)^{1-\beta}.$$

Initially, only part of the Eastern labour force adopts the new technology, since the West still retains its comparative advantage in manufacturing. However, over time, the East moves up the learning curve of the new technology, whereas productivity in the West remains stagnant at its upper bound  $\bar{A}$ . Given the superiority of the new technology, the East eventually overtakes the West in terms of productivity. We will now describe this process in further detail, giving special attention to three phenomena: first, capital flows from West to East; second, the income gap narrows and, at some point, the East overtakes the West; and, third, the specialisation pattern eventually reverses as the West loses its comparative advantage in manufacturing.

As soon as the East adopts the new technology, capital starts migrating from West to East. This follows by direct analogy with Proposition 2: capital flows to the region with the highest productivity growth. This is consistent with the results of Brezis and Tsiddon (1998) who provide empirical evidence suggesting that the loss of a country's economic leadership goes together with capital exports. As capital flows into the East and productivity increases, the East becomes more and more specialised in manufacturing and the per capita income gap between the two regions narrows (Figure 3). This can easily be seen by analogy with (16) and (17). At the point when the East's manufacturing productivity rises above the West's, the East overtakes the West in terms of income per capita.<sup>15</sup> At the same time, the specialisation pattern reverses. The East becomes fully specialised in manufacturing, and the West starts producing food.

*Case 2: Convergence or reinforcement of development pattern*

$$A'[S^*(t')] > \bar{A}.$$

If  $A'[S^*(t')] > \bar{A}$ , the West adopts the new technology; the outcome, however, will depend on whether spillovers are zero or strictly positive.

- *No spillovers*

If there are no spillovers, as in Brezis *et al.* (1993), then  $A'[S^*(t')] = \underline{A}'$ , so that the West's manufacturing productivity at time  $t'$  is  $\underline{A}'$ . This means that the East and the West have identical productivities in both food and manufactures. This leads to an indeterminacy, given that both capital and goods are perfectly mobile.

<sup>14</sup> In other words, since the East has access to the new technology, the relative productivity advantage of the West drops and the economy reverts to an equilibrium of partial specialisation, where the East produces both goods.

<sup>15</sup> Note that overtaking would be less likely in a model with savings. As pointed out in the last paragraph of Section 1, the West would own a relatively greater capital stock, thus making it more difficult for the East to leapfrog.

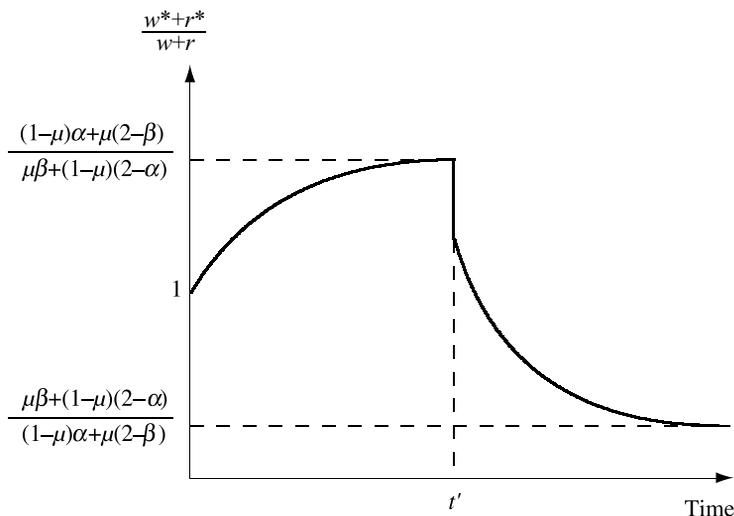


Fig. 3. Relative Income Per Capita: Reversal (Case 1)

On the one hand, specialisation may arise along the predictions of the standard Heckscher–Ohlin model. Since the West is capital-abundant<sup>16</sup> and manufacturing capital-intensive, the West specialises in the new technology. Although this temporarily leads to factor price equalisation, productivity in the West increases over time, causing once again income divergence.

On the other hand though, capital mobility, rather than trade, may equalise returns across regions. In that case capital–labour ratios become identical in East and West; comparative advantage disappears and each region becomes fully self-sufficient. Moreover, since both regions produce the same amount of manufactures, they move up the industry’s learning curve in a synchronised manner, so that neither is able to gain a comparative advantage in the new industry. Both regions have become identical; the development gap has vanished, income per capita has converged, and there are no capital flows. Note that this is the equilibrium Brezis *et al.* (1993) would have found if they had analysed Case 2, where the new technology proves attractive to both regions: East and West become identical and remain identical.<sup>17</sup>

- *Strictly positive spillovers*

If spillovers are strictly positive, then  $A'[S^{*}(t')] > \underline{A}'$ ; it is thus clear that the West retains its comparative advantage in manufacturing. All workers in the West adopt the new technology, whereas the East may either remain fully specialised in food or partially adopt the new technology. If nobody in the East switches to the new technology, the West’s relative income per capita advantage remains intact at (22) and capital has no incentive to move. If, on the contrary, some

<sup>16</sup> This can easily be seen from (20), where, as mentioned before,  $K$  and  $K^*$  refer to the capital stock’s physical location, and not to its ownership.

<sup>17</sup> This is obvious: productivities are identical across regions and there cannot be any differences in relative factor endowments in a Ricardian model.

workers in the East adopt the innovation, the regional income gap narrows and some capital reallocates from West to East. This effect will only be temporary though if, by analogy with (18), manufacturing productivity grows faster in the West than in the East. In that case, the capital that moved East flows back West, the East returns to full specialisation in food, and the West's relative income rises to its original level (22), as illustrated by Figure 4.

This result shows that it is not enough for the backward region to adopt the new technology so as to catch up. If the switch to the new technology is not accompanied by comparative advantage, the lagging region will stay behind. This suggests that technology transfers may not always be the answer to underdevelopment.

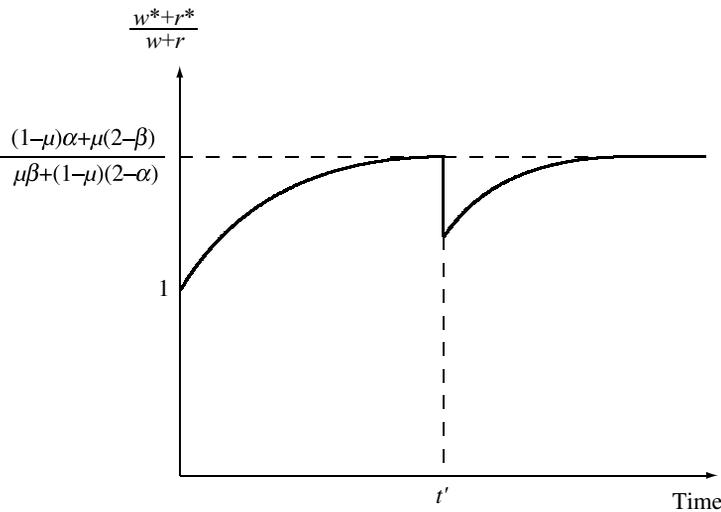


Fig. 4. Relative Income Per Capita: Reinforcement (Case 2 with strictly positive spillovers)

Case 3: Status quo

$$A'[S^*(t')] \leq \bar{A} \quad \text{and} \quad \frac{\bar{A}}{\underline{A}'} \geq \left( \frac{\mu}{1-\mu} \frac{1-\beta}{1-\alpha} \right)^{1-\beta}.$$

In this case, neither of the regions adopts the new technology. The economy remains in a status quo.

The introduction of spillovers therefore addresses two problems of the Brezis *et al.* (1993) model. First, in Brezis *et al.* the adoption of a new technology always benefits the lagging region. Indeed, in a Ricardian model without spillovers, the backward region either catches up (as explained in Case 2) or overtakes the leading region (Case 1). This seems at odds with casual observation; experience with older technologies often gives advanced regions an edge over their backward neighbours in the adoption of new technologies. For instance, Switzerland used its strength in the dye industry to move into pharmaceuticals. As mentioned in footnote 1, Brezis *et al.* are aware of this possibility; more than that,

they even suggest that leapfrogging forms the exception, rather than the rule. However, they do not go the further mile by explicitly modelling this possibility. The introduction of spillovers in our model does exactly that; depending on their strength, we see overtaking or reinforcement of the development pattern.

Second, if the new technology proves attractive to both regions, the absence of spillovers in Brezis *et al.* implies that all differences between the East and the West are erased (Case 2). Notice that, in their paper, Brezis *et al.* focus exclusively on Case 1, and avoid talking about this possibility. This is not surprising; the idea that the new technology has exactly the same productivity in the West and the East seems implausible. It implies that whatever experience each region's labour force has, or whatever each region's economic structure is, it is irrelevant to the adoption of the new technology. The introduction of spillovers in our model addresses this issue by allowing for differences in the expertise of regions.

In addition to accounting for a wider variety of development patterns, our model provides insights as to when technological change benefits the advanced or the backward region. If the new and the old technology are similar, spillovers are sufficient for the advanced region to overcome its cost disadvantage, adopt the new technology and remain in the lead. If, on the contrary, both technologies are quite different, past experience with the old technology is irrelevant, and the new industry locates wherever wages are lower.

A final advantage of our model is that capital flows can be explicitly analysed. Re-stating Proposition 2, we find that capital migrates to the region with the highest productivity growth. This sheds some further light on the debate about the direction of capital flows. Whereas the neo-classical growth model, in its simplest form, would predict capital to flow from the rich to the poor region, Lucas (1990) argues that this may not happen if there are, for instance, differences in human capital. Our model, however, says something more general, in line with the findings of Brezis and Tsiddon (1998). Capital does not necessarily flow from the rich to the poor region or from the poor to the rich region, but rather to the region which experiences fastest technological progress. As mentioned before, in the case of leapfrogging, for instance, the backward region starts attracting capital as soon as it adopts the new technology, and thus well *before* the actual overtaking takes place. This fits the empirical evidence; by analysing the overtaking of Holland by Britain in the mid-eighteenth century, and of Britain by the US at the beginning of the twentieth century, Brezis and Tsiddon (1998) find that capital inflows are a leading indicator of leapfrogging.

### 3. The Possibility of Immiserising Inter-regional Transfers

Inter-regional transfers are often used to limit the degree of regional inequality. Although transfers may improve the backward region's relative income in the short run, certain types of transfers – such as unemployment benefits and public employment – have the negative long-run effect of contributing to persistent underdevelopment. Such transfers raise the equilibrium wage without improving productivity, thus making the backward region less attractive for new technologies. Since this limits the chances of the lagging region taking off, we call these transfers

‘immiserising’.<sup>18</sup> Of course, not all transfers suffer from this problem; capital subsidies, for instance, may, in certain circumstances, increase the likelihood of the backward region taking off. In what follows, we study capital subsidies, unemployment benefits and public employment in further detail. Some empirical evidence is then provided which is consistent with our findings.

### 3.1. Capital Subsidies

Assume we start off as at the beginning of Section 3, in a situation of full specialisation with the West producing manufactures and the East food; learning has been exhausted in the West, so that manufacturing productivity is  $\bar{A}$ . The central government now decides to subsidise capital in the East. The policy is financed by taxing capital in the West. This increases the capital stock in the East, while it reduces the capital stock in the West:

$$K_s > K \quad \text{and} \quad K_s^* < K^*. \tag{23}$$

For simplicity, we assume that the economy remains fully specialised.<sup>19</sup> In that case, capital subsidies increase the equilibrium manufacturing price:

$$p_{M_s} = \frac{\mu}{1 - \mu} \frac{K_s^\alpha}{\bar{A}K_s^{r*\beta}} > p_M = \frac{\mu}{1 - \mu} \frac{K^\alpha}{\bar{A}K^{r*\beta}}. \tag{24}$$

We now introduce a new technology. Assume for the moment that the West’s productivity in the old technology is higher than in the new one:

$$\bar{A} \geq A'[S^{r*}(t)]. \tag{25}$$

This implies that the economy is either in Case 1, where the East adopts the new technology and leapfrogs, or in Case 3, where neither region adopts the new technology. Capital subsidies increase the East’s chances to take off and leapfrog by tilting the balance in favour of Case 1. To see this, consider the conditions required for the East to adopt the new technology. We need to find a capital–labour ratio  $k/l$  for which wages and returns to capital are greater in the new industry than in the food sector:

$$p_{M_s} \bar{A}' (1 - \beta) \left(\frac{k}{l}\right)^\beta > (1 - \alpha) K_s^\alpha \tag{26}$$

$$p_{M_s} \bar{A}' \beta \left(\frac{l}{k}\right)^{1-\beta} > \alpha \left(\frac{1}{K_s}\right)^{1-\alpha}. \tag{27}$$

<sup>18</sup> Although the paradox of immiserising transfers has a long tradition in trade theory, dating back to Leontief (1936), the argument in our paper is different from the standard one. Taking the standard approach, transfers are immiserising if they deteriorate the recipient’s terms of trade so much that the backward region becomes worse off; in our model, transfers are immiserising because they reduce the backward region’s chance of adopting new technologies and taking off.

<sup>19</sup> Since capital subsidies do not only increase the capital stock in the East, but also raise the manufacturing price, the East is actually less likely to remain fully specialised. However, if subsidies are not too great, this is a reasonable assumption.

Substituting  $p_{M_s}$  from (24) into the above equations gives

$$\frac{\mu}{1-\mu} \frac{A'(1-\beta)}{\bar{A}K_s^{*\beta}} \left(\frac{k}{l}\right)^\beta > (1-\alpha) \quad (28)$$

$$\frac{\mu}{1-\mu} \frac{A'\beta}{\bar{A}K_s^{*\beta}} \left(\frac{l}{k}\right)^{1-\beta} > \alpha \left(\frac{1}{K_s}\right). \quad (29)$$

Comparing conditions (28) and (29) to the case where capital subsidies are zero, it is obvious that, given (23), both conditions have become less stringent. Therefore, assuming the West does not adopt the new technology, transfers increase the chance of the backward region taking off.<sup>20</sup>

However, capital subsidies may cease to help the lagging region if condition (25) does not hold and the West switches to the new technology. Case 2 in Section 2 tells us that, in those circumstances, the West becomes fully specialised in the new technology, though some workers in the East may temporarily gain a foothold in the new industry. Over time, by analogy with (18), the West's specialisation in the new technology widens its productivity lead, and forces the East to abandon manufacturing. Though capital subsidies would allow some more workers in the East to switch to the new industry, this is unlikely to change the outcome. While the East's greater foothold in the new industry would surely slow down the productivity divergence suggested by (18), it would probably not change its sign, since the West remains fully specialised in the new technology. The East would eventually revert to food production and remain backward. Capital subsidies therefore do not always improve the odds of the lagging region.<sup>21</sup>

### 3.2. Unemployment Benefits

The case of unemployment benefits is rather different. Before analysing their effect, we slightly change the utility function, so that workers now choose between being employed and unemployed:

$$U = C_M^\mu C_F^{1-\mu} - \gamma z \quad (30)$$

where  $z = 1$  when the agent is employed, and  $z = 0$  when the agent is unemployed. The central government ensures an income  $\delta$  to unemployed workers. The scheme is financed by a proportional tax on wages in the rich region.

As before, we start off with the West fully specialised in manufacturing and the East in food; it is assumed that both regions remain fully specialised after the

<sup>20</sup> Note that we have not explicitly discussed the static effects of transfers (ie the effects before the introduction of the new technology). In fact, it can be shown that relative income per capita is not affected; changes in the allocation of capital are offset by changes in the terms of trade.

<sup>21</sup> Of course, one may argue that, in Case 2, other types of intervention would be more effective. The regional government of the East could, for instance, give specific subsidies to the new industry. However, such policies of 'picking winners' have been well studied in the literature; see, for example, Grossman, (1990) and are not our main focus; rather, we are interested in understanding which kinds of transfers are immiserising.

introduction of unemployment benefits.<sup>22</sup> Parameters are chosen in such a way that at least some agents in the East have an incentive to become unemployed. The labour market in the East reaches an equilibrium when food workers and unemployed enjoy the same utility. Since wages are higher in the West than in the East,<sup>23</sup> utility from working in manufacturing is higher than from being unemployed, so that nobody in the West chooses to be out of work. Given that both regions are fully specialised, the relative manufacturing price is then

$$p_{M_u} = \frac{\mu}{1 - \mu} \frac{K^\alpha L_F^{1-\alpha}}{AK^{*\beta}} \quad (31)$$

where  $L_F < 1$ . Note that unemployment benefits do not change the allocation of capital across regions. To see this, equalise the returns to capital in East and West:

$$r = \alpha \left( \frac{L_F}{K} \right)^{1-\alpha} = r^* = p_{M_u} A^* \beta \left( \frac{1}{K^*} \right)^{1-\beta} \quad (32)$$

Substituting (31) into (32) and solving out for  $K^*/K$ , gives the same result as in (20).

Given that  $K^*/K$  has not changed, it is clear from (31) that unemployment benefits have a negative effect on the relative manufacturing price. We now introduce a new technology, and focus on the case where the West has no incentive to switch technologies (ie (25) holds). By analogy with (28) and (29), for the East to adopt the innovation, there must be a capital–labour ratio  $k/l$  for which wages and returns to capital are higher in new manufacturing than in food:

$$p_{M_u} \underline{A}' (1 - \beta) \left( \frac{k}{l} \right)^\beta > (1 - \alpha) \left( \frac{K}{L_F} \right)^\alpha \quad (33)$$

$$p_{M_u} \underline{A}' \beta \left( \frac{k}{l} \right)^{1-\beta} > \alpha \left( \frac{L_F}{K} \right)^{1-\alpha} \quad (34)$$

We now compare conditions (33) and (34) before and after the introduction of unemployment benefits. Substituting (31) into (33) and (34), and given that  $L_F$  drops as unemployment benefits are introduced, condition (33) becomes more stringent, whereas condition (34) is unaffected.

It can thus be concluded that unemployment benefits, by raising real wages in the backward region without improving its productivity, reduce the likelihood of the East taking off.<sup>24</sup> As a side remark, note that the existence of public goods would tend to intensify this negative effect. Consider, for instance, the case of a

<sup>22</sup> Since unemployment benefits tend to lower the manufacturing price, this is equivalent to saying that benefits are not sufficiently great for manufacturing workers in the West to switch to the food sector.

<sup>23</sup> If not, the West would switch to food production.

<sup>24</sup> We have not explicitly analysed how unemployment benefits affect the backward region if the West switches to the new technology (Case 2) because the result is obvious: if the East remained backward in the absence of unemployment benefits, it will do so *a fortiori* once such benefits are introduced, since the incentive to adopt the new technology weakens.

central government providing public health care of comparable quality across regions. This would raise reservation wages in the backward region, increase its unemployment, and further limit its chances of take off.

### 3.3. *Public Employment*

The effect of public employment, often located disproportionately in backward regions and paying higher wages, has similar effects on underdevelopment as unemployment benefits. To analyse this case, let us again slightly modify our model by assuming that a fraction  $\pi$  of the total labour force needs to be employed in the public sector for the economy to run smoothly. Though these public employees are not part of the productive sector, without them, the economy would cease to operate adequately.<sup>25</sup>

Initially, public employment is equally distributed between East and West; each region has  $\pi$  public employees. Public employees are paid by introducing a proportional tax on manufacturing workers in the West. Public wages do not differ across regions, and are set equal to net manufacturing wages in the West. Assuming both regions are fully specialised, and learning has been exhausted in the West, the manufacturing price can be defined as

$$p_{M_\pi} = \frac{\mu}{1 - \mu} \frac{K^\alpha (1 - \pi)^{1-\alpha}}{\bar{A} K^{*\beta} (1 - \pi)^{1-\beta}} \quad (35)$$

Taking the equal distribution of public employment as a starting point, we now analyse how increasing the share of public employees in the backward region affects its chances to attract new technologies. Assuming both regions remain fully specialised, this policy can be shown, as in the case of unemployment benefits, not to change the allocation of capital between East and West. Since the manufacturing price decreases and the allocation of capital remains the same, the rest of the analysis is identical to the one of unemployment benefits. The increase of public employment in the backward region, therefore, contributes to the persistence of underdevelopment.

### 3.4. *A Look at Some Data: The Case of Italy's Mezzogiorno*

One of the best known cases of uneven regional development is the persistent inequality between Northern Italy and the Mezzogiorno. Although the South was converging rather rapidly in the 1960s, this process came to a halt and reversed at the beginning of the 1970s. Income per capita in the North relative to the South dropped from a level of 1.95 in 1960 to a minimum of 1.55 in 1971, and has since then steadily crawled back up, reaching a level of 1.74 in 1990 (Figure 5). Our theoretical analysis suggests that inter-regional transfers may have contributed to the Mezzogiorno's persistent underdevelopment by increasing the cost of labour, thus making Southern Italy less attractive for new investment and new technologies.

<sup>25</sup> This assumption greatly simplifies the model by not obliging us to model the public sector explicitly.

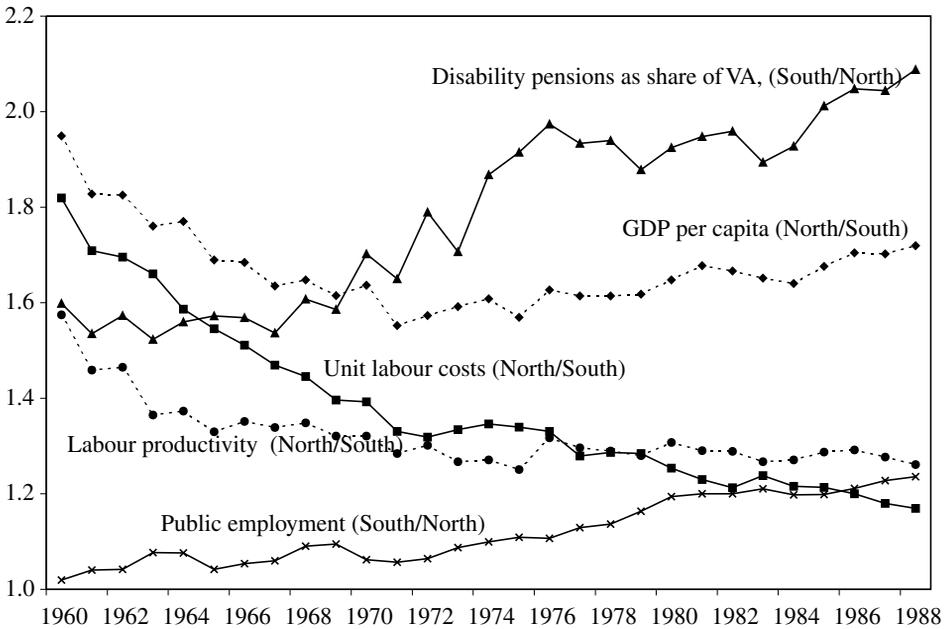


Fig. 5. *GDP Per Capita, Unit Labour Costs, Labour Productivity, Disability Pensions and Public Employment*

To see whether this theoretical possibility is consistent with the data we compare the evolution of

- 1 unemployment benefits
- 2 public employment
- 3 GDP per capita
- 4 unit labour costs and
- 5 labour productivity.

For purposes of the analysis Italy is divided in 'North' and 'South'. Following standard practice, 'North' is made up of the twelve administrative regions stretching from Valle d'Aosta in the Alps down the Lazio, the region containing Rome, whereas 'South' covers the remaining eight regions, including the islands. The time period goes from 1960 to 1990. The data are described in further detail in Appendix A.

We start by looking at unemployment benefits. Since those were virtually non-existent in Italy during the period under consideration, disability pensions are used as a proxy. We thereby follow Attanasio and Padoa Schioppa (1991), who point out that disability pensions have typically been used as a way of granting transfers to the unemployed. As can be seen in Figure 6, disability pensions as a share of value added went up significantly in the 1970s. The relative increase was much more pronounced in the South though; whereas the share was about 60% higher in the South at the end of the 1960s, it was more than double by the mid-1980s (Figure 5). Public employment as a share of total employment exhibits a similar pattern (Figure 7).

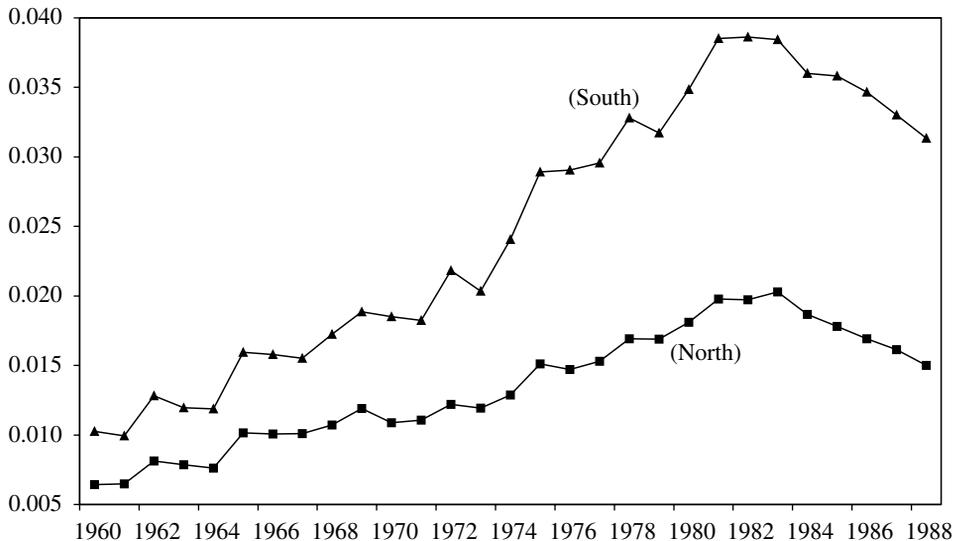


Fig. 6. Disability Pensions as a Share of Value Added

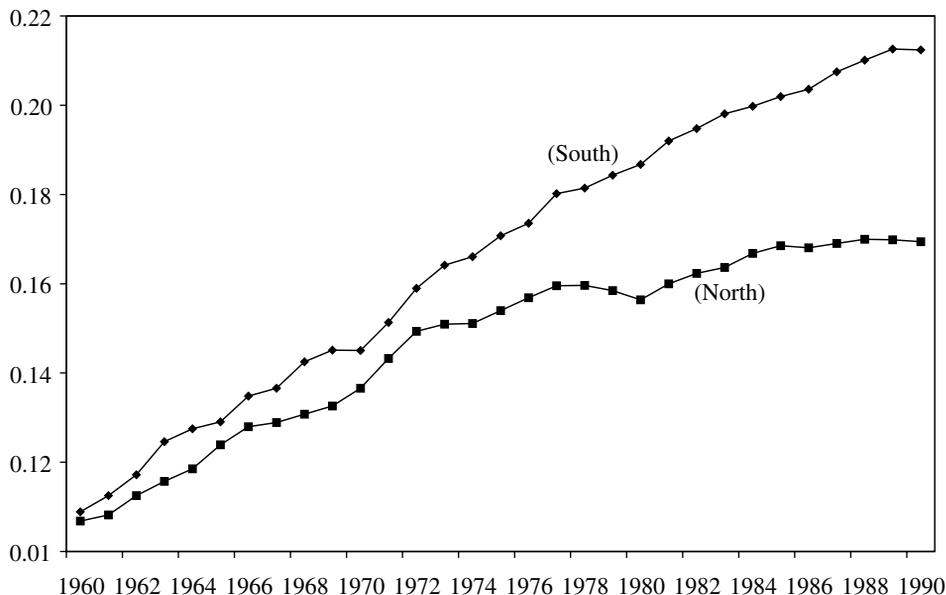


Fig. 7. Public Employment as a Share of Total Employment

Starting off with nearly identical shares at the beginning of the 1970s, by 1990 the share of public employees in the South was about 25% higher than in the North (Figure 5), corresponding to a difference of 4 percentage points.

According to our theoretical analysis, the upward trend in inter-regional transfers, starting at the beginning of the 1970s, may have kept the South locked into underdevelopment. The timing surely coincides with the reversal of convergence

in GDP per capita.<sup>26</sup> For a more complete picture though, we check some of the other theoretical predictions. In our model, transfers are immiserising because they increase labour costs, without improving productivity; this loss in competitiveness keeps new investments and technologies away. The data show that, during the 1970s and 1980s, the Mezzogiorno's competitiveness continued to slip: whereas in 1970 unit labour costs were still about 39% higher in the North, this figure had dropped to 16% by 1990 (Figure 5). For want of data on inter-regional capital flows and technology adoption, we use labour productivity as a proxy.<sup>27</sup> Again, the data confirm what we would expect. The rapid convergence of labour productivity during the 1960s came to a halt at the beginning of the 1970s (Figure 5). This suggests a stagnation in technology adoption and capital inflows.

The overall picture is therefore consistent with our theoretical predictions: inter-regional transfers may be keeping the Mezzogiorno backward. This is also the view of Boltho *et al.* (1997), who argue that the South's slowdown is related to a shift in public policy from investment incentives toward income support. A word of caution is in place though. What has been presented here are a number of correlations between variables. Causality, however, could very well have run the other way: transfers may have gone up because regions stopped converging, rather than the other way around.

#### 4. Conclusion

In this paper, we have extended the Brezis *et al.* (1993) Ricardian model of uneven development to a Heckscher–Ohlin framework with geographically mobile capital and learning spillovers. Depending on the strength of spillovers, the introduction of a new technology benefits either the lagging or the leading region. Capital flows are explicitly analysed, and are found to be consistent with the results of Brezis and Tsiddon (1998). It is then shown that certain types of inter-regional transfers have a negative effect on the growth perspectives of backward regions. Although transfers are welfare improving for the lagging region in a static sense, they may contribute to the long-run persistence of uneven development. It should be interesting for future work to explore this trade off in further detail.

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#### Appendix A: Data

The Italian 'North' is made up of the following regions: Piemonte, Valle d'Aosta, Lombardia, Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia, Liguria, Emilia-Romagna,

<sup>26</sup> Although our model defines income as GNP, for lack of data, we use GDP. The general trend should not be much different though.

<sup>27</sup> In our model, technology adoption leads to capital inflows, both of which should show up as increased labour productivity.

Toscana, Umbria, Marche and Lazio; the Italian 'South' consists of: Abruzzo, Molise, Campania, Puglia, Basilicata, Calabria, Sicilia and Sardegna.

GDP per capita, labour productivity, and public employment as a share of total employment have been downloaded from the CRENOS (*Centro Ricerche Economiche Nord Sud*) website at the University of Cagliari. The original data sources are described in detail at <http://www.crenos.unica.it>. Unit labour costs and disability pensions as a share of value added have been kindly provided by Andrea Ichino of the European University Institute. The original data sources are available from the author on request.

## Appendix B: Proofs

### *Proof of Proposition 1 part (c)*

In this proof, it is shown that (9) is *necessary and sufficient* to insure that the West is completely specialised in manufacturing. Instead of showing this directly, we first derive a necessary and sufficient condition for the West to produce some food; (9) will then be the negation of this necessary and sufficient condition.

Assume, therefore, that the East produces food and the West both food and manufactures. Given the mobility of capital, rental prices equalise across sectors and regions:

$$r = \alpha \left( \frac{1}{K_F} \right)^{1-\alpha} = \alpha \left( \frac{L_F^*}{K_F^*} \right)^{1-\alpha} = p_M A(E^*) \beta \left( \frac{L_M^*}{K_M^*} \right)^{1-\beta} = r^*. \quad (36)$$

Wages across sectors in a given region equalise. Moreover, since the food technology is identical in both regions, and since rental prices equalise across regions, it follows that food wages equalise in the East and the West. Wages are therefore identical across regions and sectors:

$$w = (1 - \alpha) K_F^\alpha = (1 - \alpha) \left( \frac{K_F^*}{L_F^*} \right)^\alpha = p_M A(E^*) (1 - \beta) \left( \frac{K_M^*}{L_M^*} \right)^\beta. \quad (37)$$

The price expression is obtained by plugging the production functions (1), (2) and (4) into the inverse demand function (7):

$$p_M = \frac{\mu}{1 - \mu} \frac{K_F^\alpha + K_F^{*\alpha} L_F^{*(1-\alpha)}}{A(E^*) K_M^{*\beta} L_M^{*(1-\beta)}}. \quad (38)$$

Rewriting (37) gives

$$p_M = \frac{1 - \alpha}{1 - \beta} \frac{K_F^\alpha}{A(E^*) (K_M^*/L_M^*)^\beta}. \quad (39)$$

Replacing  $L_M^*$  by  $1 - L_F^*$  and equalising (38) and (39) allows us to solve out for  $L_F^*$

$$L_F^* = \frac{(1 - \mu)(1 - \alpha) - \mu(1 - \beta)}{(1 - \mu)(1 - \alpha) + \mu(1 - \beta)}. \quad (40)$$

A *necessary* condition for the West to produce food is that  $L_F^* > 0$ . In other words:

$$\mu < \frac{1 - \alpha}{2 - \alpha - \beta}. \quad (41)$$

To claim that this condition is also *sufficient*, we need to show that no other conditions are necessary to insure food production in the West. Substituting (40) into (38) gives

$$p_M = \frac{1 - \alpha}{1 - \beta} \frac{K_F^\alpha}{A(E^*) (K_M^*/L_M^*)^\beta}. \quad (42)$$

Rewriting (36) gives

$$p_M = \frac{\alpha}{\beta} \frac{(1/K_F)^{1-\alpha}}{A(E^*)(L_M^*/K_M^*)^{1-\beta}}. \tag{43}$$

Equating (42) and (43) then gives

$$K_F = \frac{\alpha}{\beta} \frac{1 - \beta K_M^*}{1 - \alpha L_M^*}. \tag{44}$$

Of course, the sum of capital used in each sector should be the sum of total capital:

$$K = K_F + K_F^* + K_M^*. \tag{45}$$

Substituting (40) into (44) gives

$$K_F = \frac{\alpha}{\beta} \frac{1}{1 - \alpha} \frac{K_M^* [(1 - \mu)(1 - \alpha) + \mu(1 - \beta)]}{2\mu}. \tag{46}$$

From (36), we know that  $K_F^* = K_F L_F^*$ . From (40) and (46), we can then derive

$$K_F^* = \frac{\alpha}{\beta} \frac{1}{1 - \alpha} \frac{K_M^* [(1 - \mu)(1 - \alpha) - \mu(1 - \beta)]}{2\mu}. \tag{47}$$

Substituting (46) and (47) into (45) allows us to derive

$$K_M^* = \frac{\mu\beta}{\mu\beta + \alpha(1 - \mu)} K. \tag{48}$$

It is obvious that the coefficient in front of  $K$  in (48) is always positive. The same is true for the coefficients in front of  $K_M^*$  in (46) and (47). No other conditions are therefore necessary to insure an allocation of capital and labour across the three sectors compatible with food production in the East and food and manufactures production in the West; (41) is therefore a *necessary and sufficient* condition.

A *necessary and sufficient* condition to have the West fully specialised in manufacturing is therefore the negation of (41):

$$\mu \geq \frac{1 - \alpha}{2 - \alpha - \beta}. \tag{49}$$

*Proof of Proposition 2 part (d)*

Assume the West produces manufactures, and the East both goods. To simplify notation,  $A = A(E)$  and  $A^* = A(E^*)$ . Given the mobility of capital, rental prices equalise across sectors and regions:

$$r^* = p_M A^* \beta \left(\frac{L_M^*}{K_M^*}\right)^{1-\beta} = p_M A \beta \left(\frac{L_M}{K_M}\right)^{1-\beta} = \alpha \left(\frac{L_F}{K_F}\right)^{1-\alpha}. \tag{50}$$

Wages equalise across sectors in the East:

$$w = p_M A (1 - \beta) \left(\frac{K_M}{L_M}\right)^\beta = (1 - \alpha) \left(\frac{K_F}{L_F}\right)^\alpha. \tag{51}$$

Substituting production (1), (3) and (4) into the inverse demand function (7) gives the manufacturing price:

$$p_M = \frac{\mu}{1 - \mu} \frac{K_F^\alpha r^{(1-\alpha)}}{A^* K_M^{*\beta} + A K_M^\beta L_M^{(1-\beta)}}. \tag{52}$$

From (51), we can derive

$$\frac{K_M}{L_M} = \left(\frac{A}{A^*}\right)^{\frac{1}{1-\beta}} K_M^*. \quad (53)$$

From (50) and (51):

$$\frac{K_M}{L_M} = \frac{1 - \alpha \beta K_F}{1 - \beta \alpha L_F}. \quad (54)$$

Substituting (53) and (54) into (52) gives

$$p_M = \frac{\mu}{1 - \mu} K_M^{*(\alpha-\beta)} \frac{[(1 - \beta)/(1 - \alpha)(\alpha/\beta)]^2 (A/A^*)^{\frac{2}{1-\beta}} (1 - L_M)}{A + A(A/A^*)^{\frac{\beta}{1-\beta}} L_M}. \quad (55)$$

From (51) we have

$$p_M = \frac{1 - \alpha}{1 - \beta} \frac{1}{A} \frac{(K_F/L_F)^\alpha}{(K_M/L_M)^\beta}. \quad (56)$$

Substituting (53) and (54) into (56) gives

$$p_M = \left(\frac{1 - \alpha}{1 - \beta}\right)^{1-\alpha} \left(\frac{\alpha}{\beta}\right)^\alpha \frac{1}{A} \left(\frac{A}{A^*}\right)^{\frac{2-\beta}{1-\beta}} K_M^{*(\alpha-\beta)}. \quad (57)$$

We now equalise (55) and (56). It is obvious that  $K_M^*$  drops out, so that we can solve for  $L_M$ :

$$L_M = \frac{\mu(1 - \beta)AA^{*\frac{-\beta}{1-\beta}} - (1 - \alpha)(1 - \mu)A^{\frac{-\beta}{1-\beta}}A^*}{\mu(1 - \beta)AA^{*\frac{-\beta}{1-\beta}} + (1 - \alpha)(1 - \mu)A^{\frac{-\beta}{1-\beta}}A^*}. \quad (58)$$

For the West to actually produce manufactures, it must be that (58) > 0. This corresponds to condition (10).

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