Rational Underdevelopment*

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Abstract

We propose a two-region two-sector model of uneven development, where technological change benefits either the lagging or the leading region. In this framework inter-regional transfers may lead to persistent underdevelopment; by raising wages, transfers reduce the chance of the backward region adopting a new technology and taking off. Due to uncertainty about which region benefits from technological change, the backward region may rationally choose to remain underdeveloped, while the advanced region continues to pay transfers. The model provides a rationale for cases, such as Italy's *Mezzogiorno*, where the same rich region subsidizes the same poor region on a continuous basis.

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1 Introduction

Interregional transfers that raise wages without improving productivity have often been blamed for keeping backward regions trapped into underdevelopment. By eroding the competitiveness of lagging regions, such transfers contribute to their inability to take off. The standard textbook example is Italy, where the post-war convergence of the Mezzogiorno went into reverse at the beginning of the 1970s when public policy shifted from investment incentives to income support (Boltho, Carlino and Scaramazzino, 1997). As a result, between 1971 and 1990 unit labor costs in the South rose 23% more than in the North, while its relative GDP per capita declined from 0.65 to 0.57. Post-reunification Germany tells much the same story. Heavy subsidies and union wage setting resulted in a ten-fold jump in relative Eastern wages — from 7% in 1991 to 70% in 1998 — with relative labor productivity only increasing from 35% to 55% (Sinn, 2000).[1] Not before long, the new *Länder* had earned the dubious distinction of being called the *Mezzogiorno on the Elbe*.[2]

Transfers that lock backward regions into underdevelopment seem hard to make sense of. Why would the South be willing to accept transfers if they imply giving up the possibility of taking off? And why would the North want to pump money into a bottomless well? The contribution of this paper is to show how such transfers can be rationalized. That transfers may have a negative impact on the backward region's development is well known; how they can be sustained in equilibrium is not.

To analyze this issue, we propose a two-period model of uneven regional development inspired by Brezis, Krugman and Tsiddon (1993) and Desmet (2002). In the first period the economy is divided into a rich manufacturing North and a poor agricultural South. In the second period we introduce a new manufacturing technology, which can either locate in the backward South — attracted by its low wages — or in the advanced North — if spillovers from the previous technology are sufficiently strong to compensate

[1] Most tranfers come in the form of social security payments, therefore pushing up reservation wages (Sinn and Westermann, 2001). Moreover, the magnitude of transfers — more than 30% of Eastern GDP in 1999 — is clearly linked to union wages. By causing an important increase in unemployment, union wages increase the demand for transfers.

[2] See Giersch and Sinn (2000).

for the higher wages. Inter-regional transfers raise wages in the backward region, reducing its chance to adopt the new technology and take off. With high enough transfers, the backward South never adopts the new technology, and is doomed to remain backward.

The main result of the paper is that transfers condemning the backward region to underdevelopment may Pareto dominate (lower) transfers that give the backward region a chance to take off. This is what we call *rational underdevelopment*. The advanced region gives transfers to protect itself against low-wage competition, thus keeping the backward region from taking off and ensuring its dominant position; the backward region accepts those transfers — and rationally chooses to remain backward — because even without transfers it is not sure to benefit from the new technology. In this framework transfers serve a two-fold purpose: they provide insurance against the uncertain effects of technological change, and they lead to consumption smoothing between the first and the second period.

Our paper is related to the well known transfer paradox, dating back to Leontieff (1936). This paradox refers to the possibility of transfers benefiting the donor country through an improvement in its terms of trade. If the gains from more favorable terms of trade are enough to compensate the losses from paying transfers, the donor country ends up better off. Although this suffices to show why rich countries may be interested in paying transfers, it falls short in explaining why poor countries are willing to accept them.

The same failure to endogenize transfers afflicts Desmet (2002). That paper limits itself to showing how transfers can make backward regions worse off; it remains silent on whether such policies could be sustained in equilibrium. This is also true for the empirical work on the Mezzogiorno and Eastern Germany (Boltho et al., 1997; Sinn, 2000; Sinn et al., 2001). If anything, the common tone is that these regional policies have been misplaced. Our paper claims this is not necessarily the case.

Of course there exist models that explain why transfers arise in equilibrium. A first class of such models argues that interregional transfers can be used to limit distortions. Of particular interest is Wildasin (1994), who shows that local redistributive policies in the rich region may lead to an inefficiently high level of migration. In that case using transfers to stem migration may make everyone better off. However, unlike in our model, having distortionary public policy is a precondition for transfers to be Pareto improving. A second class of models argues that transfers can be justified as a risk sharing device against asymmetric shocks (Alesina and Perotti, 1995; Persson and Tabellini, 1996a, 1996b). Asymmetric shocks imply two-way tranfers: region A is willing to subsidize region B because at some future date B will subsidize A. "Taking turns" is essential to sustain such risk sharing. This setup can therefore not explain the Mezzogiorno problem: one-way transfers, where the same rich region subsidizes the same poor region on a continuous basis.

In addition to the distinct mechanism we use to justify transfers, there is a more fundamental difference that sets our work apart from the two classes of models we just referred to. Endogenizing transfers that do not contribute to the South's backwardness — as in Wildasin (1994) and Persson and Tabellini (1996a, 1996b) — is one thing. Explaining transfers that harm the lagging region's development prospects is another. In that sense our paper goes one step further by incorporating the widely held view that public policy, rather than solving the "Southern question", forms an integral part of the Mezzogiorno's failure (Boltho *et al.*, 1997; Alesina *et al.*, 1999). In the absence of transfers the South has a chance of taking off; by accepting transfers, the South gives up this opportunity. Even so, transfers may be Pareto improving.

2 The model

The basic structure of the model follows closely Brezis, Krugman and Tsiddon (1993) and Desmet (2002). Consider two regions, North and South. Variables referring to the South are denoted by an asterisk. Labor is the only factor of production and is geographically immobile.[3] While criticizable in the case of the U.S., this latter assumption seems reasonable in the European context: as suggested by Eichengreen (1993) and Decresssin and Fatás (1995), labor mobility between European regions roughly the same size as U.S. states is extremely low.

[3]Since there are no skill differences between North and South, uneven development would disappear if labor were perfectly mobile. Note, however, that a similar outcome could be obtained in a model with labor mobility, as long as we allow for skill differences between regions (see Desmet, 2000).

The size of the labor force is the same in both regions:

$$L = L^* = 1$$

Let Q_F (Q_M) denote output of food (manufactures), and L_F (L_M) labor employed in food (manufactures). Food technologies are identical in North and South :

$$Q_F = L_F \tag{1}$$

$$Q_F^* = L_F^* \tag{2}$$

Manufacturing production, however, is subject to region-specific learning externalities, so that manufacturing technologies differ across regions:

$$Q_M = AL_M \tag{3}$$

$$Q_M^* = A^* L_M^* \tag{4}$$

All consumers have identical preferences:

$$U(C_M, C_F) = v(C_M^{\mu} C_F^{1-\mu}) \tag{5}$$

where v is a strictly increasing and strictly concave function; C_F and C_M denote the consumption of food and manufactures; and $\mu > 1/2$.[4] Consumers, therefore, are risk averse, and spend a fraction μ of their income on manufactures. After normalizing the food price to 1, the inverse demand function of manufactures relative to food is:

$$\frac{C_M}{C_F} = \frac{\mu}{1-\mu} \frac{1}{p_M} \tag{6}$$

where p_M denotes the manufacturing price.

The model consists of two periods: in period 1 productivity differences lead the economy to diverge into a rich manufacturing North and a poor agricultural South; in period 2 a new manufacturing technology is introduced, which either reinforces or reverses this pattern of uneven development. In what follows we study in turn each period.

[4] This ensures uneven development between both regions. Without this assumption, both regions would produce food, and wages would equalize.

2.1 Period 1

In period 1 the economy is fully specialized: the North produces manufactures, and the South produces food. Plugging production into (6) gives us the equilibrium manufacturing price:

$$p_M = \frac{\mu}{1-\mu}\frac{1}{A} \tag{7}$$

For full specialization to be an equilibrium, nobody in the South should have an incentive to switch to manufacturing production, so that:

$$1 > \frac{\mu}{1-\mu}\frac{A^*}{A} \tag{8}$$

In other words, the productivity advantage of the North needs to be sufficiently large compared to the relative importance of manufacturing consumption, so that the North is able to satisfy on its own all of the economy's manufacturing demand. Likewise, no workers in the North should have an incentive to switch to food; this result is immediate, since $\mu > 1/2$. Given the manufacturing price (7), relative wages are:

$$\frac{w}{w^*} = \frac{\mu}{1-\mu} \tag{9}$$

The economy is therefore divided into a rich manufacturing North and a poor agricultural South.

The central government now reduces regional inequality by limiting the rich region's relative wage to α, where $1 \leq \alpha \leq \frac{\mu}{1-\mu}$; the smaller α, the greater the degree of redistribution. If $\alpha = \frac{\mu}{1-\mu}$, we are in the laissez faire case with no inter-regional transfers; if $\alpha = 1$, we are at the other extreme, with maximum redistribution and wages equalizing across regions.

The value of α is decided at the beginning of the first period, and lasts until the end of the second period. In a two-period model — unlike in an infinite horizon model — such a policy is time-inconsistent: the rich region has no incentive to subsidize the poor region in the second period. Although for reasons of simplicity we stick to a setup with two periods, we should think of our model as the reduced form of a time-consistent infinite horizon model. Appendix A discusses this point in further detail.

Inter-regional redistribution is implemented by taxing manufacturing workers in the rich region, and subsidizing food workers in the poor region. The redistribution policy does not affect production.[5] Given homothetic preferences, the relative manufacturing price does not change either. Only wages are affected by redistribution.

Since in the first period Northern taxes subsidize Southern workers, wages drop in the North and rise in the South:

$$w = p_M A - t \tag{10}$$

$$w^* = 1 + t^* \tag{11}$$

where the tax t and the subsidy t^* are such that:

$$\frac{w}{w^*} = \alpha \tag{12}$$

Assuming a balanced budget, we have:

$$t = t^* \tag{13}$$

Using (7) and (10)-(13), we can derive wages, as a function of α, in both regions:

$$w = \frac{1}{1-\mu}\frac{\alpha}{1+\alpha} \tag{14}$$

$$w^* = \frac{1}{1-\mu}\frac{1}{1+\alpha} \tag{15}$$

This translates into the following utilities for North and South in period 1:[6]

$$U_1(\alpha) = v(\frac{\alpha}{1+\alpha}A^{\mu}) \tag{16}$$

$$U_1^*(\alpha) = v(\frac{1}{1+\alpha}A^{\mu}) \tag{17}$$

[5] To see this, note that nobody has an incentive to switch sectors: in the North manufacturing wages continue to be higher than food wages since $\alpha \geq 1$; in the South nobody had an incentive to switch to manufacturing in the absence of transfers, so that *a fortiori* nobody wants to switch once transfers are introduced.

[6] To see this, maximize utility (5) subject to the standard budget constraint, where income is given by (14) or (15) and the manufacturing price is (7).

Not surpringly, redistribution increases welfare in the South, and decreases welfare in the North.

Higher wages make the South less attractive for new industries.[7] Inter-regional transfers may thus contribute to persistent underdevelopment. The next section will develop this argument in detail. Though the focus will be on wage subsidies, we will claim that other types of transfers, such as unemployment benefits and public employment, have the same effect.

2.2 Period 2

In period 2 a new manufacturing technology is exogenously introduced. Although neither region has any direct experience with the new technology, the North benefits from learning spillovers coming from the old technology. These spillovers may be large or small, depending on the similarity between the two technologies.

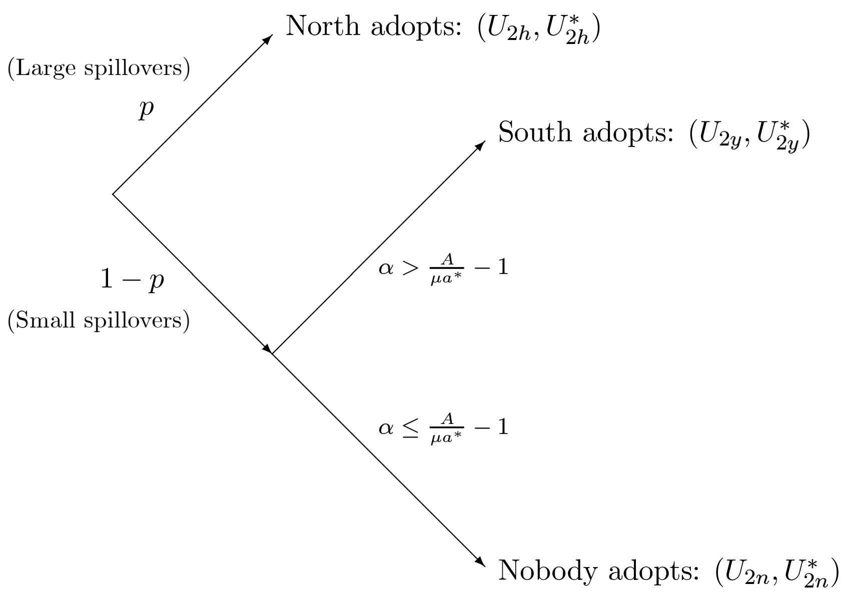

Figure 1: Adoption of new technology.

[7] In our competitive market structure workers and firms are one and the same: a wage subsidy therefore reduces the incentive to adopt new technologies or move into new industries. This suggests that our model would fall apart if firms and workers were separate entities and transfers were directly paid to workers. However, we will argue later on that our result stands up against this criticism, as long as we are willing to deviate from a perfectly inelastic labor supply.

As can be seen in Figure 1, with probability p spillovers are large, and the North's productivity in the new technology is high: $a_h > A$; with probability $1 - p$ spillovers are small, and the North's productivity in the new technology is low: $a_l < A$. Since the South does not benefit from learning spillovers,[8] its productivity in the new technology is in either case below that of the North: $a^* < a_l < a_h$.

Once a region adopts the new technology, it starts accumulating experience and moves up the new technology's learning curve. Productivity increases until it reaches a maximum $\widehat{A} > A$, at which point learning gets exhausted. For reasons of simplicity — and without loss of generality — we assume that learning happens instantaneously. This allows us to ignore the transition phase, so that the model boils down to a simple discrete two-period problem.[9]

The effect of the new technology on the development of the North and the South depends on where the new technology locates. In what follows we distinguish between three cases: the North adopts the new technology; the South adopts the new technology; or neither region adopts the new technology.

Case 1: the North adopts the new technology

In the case of large spillovers, which occurs with probability p, the North adopts the new technology (since $a_h > A$), whereas the South remains stuck in agriculture.[10] The specialization pattern has not changed; the only difference is that the North now uses a superior manufacturing technology. Given learning happens instantaneously, period 2 utilities for North and South are, by analogy with (16) and (17):

$$U_{2h}(\alpha) = v(\frac{\alpha}{1+\alpha}\widehat{A}^{\mu}) \tag{18}$$

$$U^*_{2h}(\alpha) = v(\frac{1}{1+\alpha}\widehat{A}^{\mu}) \tag{19}$$

[8] There are no spillovers between the food technology and the new manufacturing technology.

[9] For a full-blown continuous-time approach, which explicitly takes into account the learning dynamics, see Brezis, Krugman and Tsiddon (1993) and Desmet (2002).

[10] Of course the South may also adopt the new technology if, by doing so, its workers earn higher wages, i.e., if $\mu\frac{a^*}{a_h} > \frac{1}{1+\alpha}$. We will assume this condition is never satisfied. See Desmet (2002) for a more detailed discussion of this possibility.

Spillovers have allowed the North to attract the new technology in spite of its higher wages. The North reinforces its dominant position, whereas the South remains trapped in underdevelopment.

Case 2: the South adopts the new technology

In the case of small spillovers, which occurs with probability $1-p$, the North does not adopt the new technology (since $a_l < A$). The South, however, does adopt the new technology if its workers can earn higher wages by switching from food to the new technology. As can be seen in Figure 1, this happens if $p_M a^* > \frac{1}{1-\mu}\frac{1}{1+\alpha}$, or, equivalently, if redistribution is relatively limited:[11]

$$\alpha > \frac{A}{\mu a^*} - 1 \tag{20}$$

Once the South adopts the new technology, it starts moving up its learning curve. Since the new technology is superior to the old technology, the South overtakes the North and the specialization pattern reverses: the South becomes rich and industrialized, and the North poor and agricultural.[12] Assuming learning happens instantaneously, period 2 utilities in North and South are:[13]

$$U_{2y}(\alpha) = v(\frac{1}{1+\alpha}\widehat{A}^{\mu}) \tag{21}$$

$$U^*_{2y}(\alpha) = v(\frac{\alpha}{1+\alpha}\widehat{A}^{\mu}) \tag{22}$$

The new technology has located in the low-wage South, helping that region to take off and leapfrog. This picture fits the example of Belgium, where during the 1960s the rural North overtook the industrialized South. As the traditional heavy industries of the South

[11] Note that condition (20) takes the manufacturing price as given. It therefore represents the incentive for a worker in the South to adopt the new technology, assuming nobody else does. Although the manufacturing price would of course change if expectations were that others would adopt the new technology too, this would not strengthen the incentive to adopt. If others would switch to the new technology, the manufacturing price would drop, making adoption of the new technology less attractive. Therefore, for at least one worker to adopt the new technology in equilibrium, condition (20) must hold.

[12] We assume the condition for full specialization is satisfied.

[13] The subscript y stands for *"yes, the South adopts"*.

declined, new activities, such as plastics and lighter metals, located in the North, attracted by its low wages. This eventually led to leapfrogging: whereas in 1950 GDP per capita in the North was still 14% lower than in the South, by 1990 it was 31% higher.

Though not profitable from an individual agent's point of view, adopting the new technology in the North may be welfare-improving for that region. Intervention by the regional government may thus be called for. We discard such intervention arguing that the government cannot possibly know the future value of a new technology. This may seem to contradict our assumption that redistribution is decided knowing the new technology's productivity $\widehat{A}$. However, think of our model as the reduced form of a more realistic setup where many new technologies emerge, most of which flounder. The government knows that one of those new technologies will have productivity $\widehat{A}$, but it does not know which one. In that case subsidies across the board may be too expensive, whereas "picking winners" may be impossible because of informational limitations;[14] attempts suggest that government failure typically outweighs market failure.[15]

Case 3: neither region adopts the new technology

The third possibility consists of neither region adopting the new technology. As suggested by Figure 1, this occurs when spillovers are small (in the North the old technology remains more productive) and when redistribution is relatively high (in the South wages continue to be higher in the food sector):

$$\alpha \leq \frac{A}{\mu a^*} - 1 \tag{23}$$

In that case nothing changes; period 2 utilities in North and South coincide with period 1 utilities:[16]

$$U_{2n}(\alpha) = v(\frac{\alpha}{1+\alpha} A^\mu) \tag{24}$$

[14] For a survey, see Grossman (1990). Similar problems arise when trying to implement policies to support infant industries in developing countries. See Grubel (1993) for theoretical arguments, and Krueger and Tuncer (1982) for one of the few empirical tests.

[15] We borrow this turn of phrase from Krueger (1990).

[16] The subscript n stands for *"no, the South does not adopt"*.

$$U_{2n}^*(\alpha) = v(\frac{1}{1+\alpha}A^\mu) \tag{25}$$

Whether the economy is in Case 2 or in Case 3 depends on whether condition (20) or (23) is satisfied. The degree of redistribution therefore determines whether the South has a chance to develop and leapfrog. If redistribution is too high (Case 3), the South is sure to remain backward; at lower levels of redistribution (Case 2), the South may take off. This allows us to define the following two subsets of α:

Definition 1. *For a given μ, a^* and A, we define Γ as the set of α for which the South never adopts the new technology (condition (23) holds); and we define Γ^c as the set of α for which the South has a chance of adopting the new technology (condition (20) holds).*

The effect of subsidies to food workers is straightforward: by raising wages in the South, subsidies make the region less attractive for new industries, thus leading to persistent underdevelopment. This suggests, for instance, that the European Union's income support system for farmers contributes to keeping poor agricultural regions poor.

One could argue that this problem would disappear if subsidies were extended to all workers in the South, including those who switch to the new technology. Since this would leave the sectoral wage difference unchanged, technology adoption would be unaffected. But this critique is unconvincing: as soon as we deviate from our perfectly inelastic labor supply, the problem is likely to resurface. Income subsidies would reduce the labor supply in the South, pushing up the relative price of food and raising the wage level. This would obviously make it less attractive for the South to adopt the new manufacturing technology.

Another potential criticism is that our results would change if firms and workers were separate entities. The reasoning goes as follows: if subsidies were paid directly to workers, the firms' relative costs would remain the same, thus leaving the decision to adopt the new technology unchanged. However, here again the argument unravels if the labor supply is elastic: since wage subsidies would reduce the labor supply, the relative price of food would increase, making it less likely that the South switches to the new manufacturing technology.

It is also important to note that our results are not limited to the specific example of direct wage subsidies. Any policy that increases wages without improving productivity — such as unemployment benefits or public employment — would have a similar effect (Desmet, 2002).

2.3 Putting the two periods together

Let β be the common discount factor for both regions.[17] The discounted sum of expected utility in the North depends on whether the South leapfrogs or not:

$$U_y(\alpha) = U_1(\alpha) + \beta[pU_{2h}(\alpha) + (1-p)U_{2y}(\alpha)] \tag{26}$$

$$U_n(\alpha) = U_1(\alpha) + \beta[pU_{2h}(\alpha) + (1-p)U_{2n}(\alpha)] \tag{27}$$

Similarly, the discounted sum of expected utility in the South depends on whether it takes off or not:

$$U_y^*(\alpha) = U_1^*(\alpha) + \beta[pU_{2h}^*(\alpha) + (1-p)U_{2y}^*(\alpha)] \tag{28}$$

$$U_n^*(\alpha) = U_1^*(\alpha) + \beta[pU_{2h}^*(\alpha) + (1-p)U_{2n}^*(\alpha)] \tag{29}$$

Summarizing, total expected utility in North and South can be written as:

$$U(\alpha) = \begin{cases} U_y(\alpha) & \text{if } \alpha \in \Gamma^c \\ U_n(\alpha) & \text{if } \alpha \in \Gamma \end{cases} \tag{30}$$

$$U^*(\alpha) = \begin{cases} U_y^*(\alpha) & \text{if } \alpha \in \Gamma^c \\ U_n^*(\alpha) & \text{if } \alpha \in \Gamma \end{cases} \tag{31}$$

3 Rational underdevelopment

High enough transfers ensure the South remains backward. We now want to show that such transfers may be Pareto superior to any other level of transfers where the South takes off. In other words, the South chooses to remain poor, and the North chooses to continue paying transfers. This is what we call rational underdevelopment.

[17] Taking a common discount factor tends to bias the results against our favor. If the South were to have a lower discount factor than the North — a reasonable assumption since the South is poorer — it would be more willing to give up development tomorrow for income today.

Definition 2. *A redistribution policy* $\alpha \in \Gamma$ *leads to rational underdevelopment if* $U(\alpha) \geq U(\alpha')$ *and* $U^*(\alpha) \geq U^*(\alpha')$ *for all* $\alpha' \in \Gamma^c$*. We denote by* Γ^{RU} *the set of such redistribution policies.*

Our goal in this section is to show that the set of redistribution policies leading to rational underdevelopment is not empty. Such transfers serve as an insurance device for both regions. By giving transfers, the North keeps the South backward, thus making sure it remains in the lead. The South, on the other hand, prefers the certainty of transfers — and relative backwardness — to the uncertainty of taking off. In addition to risk sharing, transfers lead to consumption smoothing: the North gives up income in the first period for higher expected income in the second period, and the opposite happens in the South. Although both motives cannot be neatly separated in our particular setup, arguably risk sharing is the dominant factor. In the absence of uncertainty, consumption smoothing would most likely occur through private capital markets, without affecting the incentives to adopt new technologies.[18]

Figure 2 gives a graphical example of rational underdevelopment. It shows utility in function of redistribution. For high levels of redistribution — $\alpha \in \Gamma$ — the South never adopts the new technology. In that case the North wants to minimize redistribution, whereas the South wants to maximize redistribution; this shows up in the North's utility increasing in α and the South's utility decreasing in α. For low levels of redistribution — $\alpha \in \Gamma^c$ — both the North and the South have a chance of attracting the new industry. At the cut-off point between Γ and Γ^c the utility functions experience a discrete jump. Since the North prefers the South not adopting the new technology,[19] the North's utility at the cut-off point between Γ and Γ^c is such that $U_n(\alpha) > U_y(\alpha)$. By analogy, the opposite happens in the South.

[18]Moreover, we could easily generate rational underdevelopment in a framework without consumption smoothing. To see this, consider a two-period model with a new technology arriving in each period. In order to pool risk, regions decide at the beginning of the first period (before the first technological shock) on a redistribution scheme for the two periods. If redistribution affects wages, it will also affect technology adoption.

[19]We are thus assuming that the new technology's productivity increase is not too large; Condition 2 discusses this point in further detail.

Figure 2: Example of rational underdevelopment

Rational underdevelopment occurs if there are levels of redistribution where the South is sure to remain backward, and which are Pareto superior to any other level of redistribution where the South has a chance of taking off. This corresponds to set $\Gamma^{RU} \subset \Gamma$ in Figure 2: for all $\alpha \in \Gamma^{RU}$, utilities in North and South are superior to utilities associated to any $\alpha \in \Gamma^{c}$.

Before analytically proving that rational underdevelopment may exist, we put some more structure on the problem. First, for the North to have any interest in paying transfers, it should be uncertain to attract the new technology, and it should care about this second period uncertainty:

Condition 1. $p < 1$ and $\beta > 0$

Second, if the new technology's productivity gain is too large, the North may experience welfare gains from the South switching to the new technology; although the North would lose out on the new technology, it would be more than compensated by the decline in the relative manufacturing price. Rational underdevelopment would not occur because the

North would prefer the South adopting the new technology to nobody adopting the new technology. To avoid this case, we put an upper limit on the new technology's productivity gain:

Condition 2. $(\frac{\widehat{A}}{A})^{\mu} < \frac{\mu}{1-\mu}$

Third, focusing on the range of redistribution policies for which neither region adopts the new techology, the North's maximum level of redistribution should be higher than the South's minimum level of redistribution. The North's maximum level of redistribution $\widehat{\alpha}$ is the level above which it prefers zero transfers; the South's minimum level of redistribution $\widehat{\alpha}^*$ is the level below which it prefers zero transfers. Therefore, $\widehat{\alpha}$ is the solution to $U_n(\widehat{\alpha}) = U_y(\frac{\mu}{1-\mu})$; and $\widehat{\alpha}^*$ is the solution to $U_n^*(\widehat{\alpha}^*) = U_y^*(\frac{\mu}{1-\mu})$.[20] This gives us the third condition:

Condition 3. $\widehat{\alpha} < \widehat{\alpha}^*$

We do not provide the complete set of parameters which satisfy Condition 3, because that set depends in a non-trivial way on p, μ, A, A^*, β and the specific utility function v.

It is, however, easy to see that higher risk aversion increases the demand for transfers in both regions, and thus favors Condition 3. To illustrate this point, compare the cases of no risk aversion and very high risk aversion. In the case of no risk aversion, transfers never increase the economy's total utility, so that they cannot make both regions better off. One region's gain is always the other region's loss, so that Condition 3 is never satisfied. As risk aversion goes up, the possibility of a "bad" outcome starts to weigh heavier in a region's utility: the North becomes increasingly concerned about falling behind, and the South becomes increasingly worried about being backward. Since transfers mitigate the "bad" outcome in both regions, at high levels of risk aversion it becomes easier to find a set of transfer policies which are welfare improving for both North and South, so that

[20] If $U_n(\alpha) > U_y(\frac{\mu}{1-\mu})$ for all $\alpha \in \Gamma$ we take $\widehat{\alpha} = 1$; and if $U_n^*(\alpha) > U_y^*(\frac{\mu}{1-\mu})$ for all $\alpha \in \Gamma$ we take $\widehat{\alpha}^* = \frac{A}{\mu a^*} - 1$. Likewise, if $U_n(\alpha) < U_y(\frac{\mu}{1-\mu})$ for all $\alpha \in \Gamma$ we take $\widehat{\alpha} = \frac{A}{\mu a^*} - 1$; and if $U_n^*(\alpha) < U_y^*(\frac{\mu}{1-\mu})$ for all $\alpha \in \Gamma$ we take $\widehat{\alpha}^* = 1$. Since $U_n(\alpha)$ is strictly increasing and $U_n^*(\alpha)$ is strictly decreasing $\widehat{\alpha}$ and $\widehat{\alpha}^*$ are well defined.

Condition 3 becomes more likely to hold.[21]

We are now ready to prove analytically that under certain conditions rational underdevelopment exists:

Theorem 1. *Let Conditions 1, 2 and 3 hold. Let all parameters but a^* be fixed. Then, there exists $k \leq A$, such that for all $a^* \leq k$ we have rational underdevelopment, i.e. the set Γ^{RU} is not empty.*

Proof. See Appendix B.

Summing up, rational underdevelopment tends to occur if productivity gains deriving from the new technology are modest (Condition 2); risk aversion is high (Condition 3); and the new technology's initial productivity in the South is low (Theorem 1). All these conditions have been discussed before, except the last one, which has an easy interpretation: for a low value of a^* the South only adopts the new technology if its wages are low too. In that case a modest transfer scheme may be enough to keep the South from attracting the new technology. Some of these points will be discussed in the next section using numerical examples.

Before continuing, note that one may find our analysis too restrictive. We have shown the possibility of rational underdevelopment for the case of wage subsidies. However, there may very well exist other Pareto superior policy instruments that do not keep the South backward, in which case our example of rational underdevelopment could hardly be called rational. In principle, this is a potentially important criticism, especially since rational underdevelopment leads to an inefficiency: with a strictly positive probability neither region adopts the new technology. In practice, however, as the following paragraphs will reveal, it is not obvious which other policy could provide a way out.

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[21] We now show this result for the particular case where $a^* = \frac{1-\mu}{\mu}A$. (The result can easily be generalized.) Take the South and determine $\widehat{\alpha}^*$ by solving $v(\frac{1}{1+\widehat{\alpha}^*}A^\mu) + \beta[pv(\frac{1}{1+\widehat{\alpha}^*}\widehat{A}^\mu) + (1-p)v(\frac{1}{1+\widehat{\alpha}^*}A^\mu)] = v((1-\mu)A^\mu) + \beta[pv((1-\mu)\widehat{A}^\mu + (1-p)v(\mu\widehat{A}^\mu)]$. As risk aversion increases, agents become more worried about the "bad" outcome: the left hand side of the above equation tends to $(1+\beta)v(\frac{1}{1+\widehat{\alpha}^*}A^\mu)$ and the right hand side tends to $(1+\beta)v((1-\mu)A^\mu)$. As risk aversion goes to infinity, the problem boils down to solving $\frac{1}{1+\widehat{\alpha}^*}A^\mu = (1-\mu)A^\mu$, so that $\widehat{\alpha}^* = \frac{\mu}{1-\mu}$. In other words, any level of transfers makes the South better off. Following the same methodology for the North, as risk aversion goes to infinity, $\widehat{\alpha}$ is the solution to $\frac{\widehat{\alpha}}{1+\widehat{\alpha}}A^\mu = (1-\mu)\widehat{A}^\mu$. Given Condition 2, it is easy to see that $\widehat{\alpha} < \frac{\mu}{1-\mu}$, so that $\widehat{\alpha} < \widehat{\alpha}^*$.

In a more realistic setup with an elastic labor supply and the possibility of unemployment, many of the standard regional policy instruments would have the same effect as the wage subsidies in our model. Whether we are considering publicly provided goods, unemployment benefits, or public employment, all of these policies either reduce the labor supply, or lead to an increase in the reservation wage (Desmet, 2002). Either way, the equilibrium wage in the backward region rises, without being accompanied by a productivity increase, so that the possibility of rational underdevelopment remains. The same would be true if (lumpsum) transfers were paid to all workers in the South, including those adopting the new technology. The income effect would shift the labor supply schedule leftward, raising the relative price of food, and pushing up wages.

Even when assuming the income effect away, lumpsum transfers to the entire labor force of the South may not be the solution, because it is not clear what the North stands to gain. Remember that one of the North's incentives in paying transfers is to keep the South from taking off, and thus protect itself against low-wage competition. In the case of German reunification, for instance, the rich West was willing to put up with high transfers to the poor East because those policies protected Western jobs (Sinn and Sinn, 1992). In the absence of income effects, lumpsum transfers would not reduce competition from the poorer region, so that the richer region may be uninterested in supporting such a policy.[22]

As for subsidies to infrastructure or capital, which may actually increase the backward region's chance to take off, the same argument applies: the North may not be interested. Moreover, subsidizing infrastructure or capital is not free from distortions: by allocating too much infrastructure or capital to the backward region, these subsidies intro-

[22] To check this argument, take the parameter values of the numerical exercises in Section 4, and compare lumpsum transfers to all workers (transfers which do not distort the South's incentive to adopt new technologies) to wage subsidies to food workers (the transfers considered in this paper). Assume, as above, that transfers are set to reduce income (or consumption) inequality to a level which remains constant for the two periods. For all the parameter values used in Section 4, it turns out that the North always prefers transfers leading to rational underdevelopment to any level of transfers which does not affect the South's incentive to switch to new technologies. This result might change though if we allowed the level of inequality α to differ between the first and the second period. However, this possibility seems rather far-off. Our model describes a stable long-run agreement between two regions. To ensure the stability of the deal, we could think of redistribution being written into the country's constitution, as is the case in Canada. In such an arrangement it seems unlikely that the levels of redistribution would experience large movements across periods.

duce inefficiencies.

4 Some numerical illustrations

Consider the following baseline case. Take the CRRA utility function $v = \frac{x^{1-\rho}}{1-\rho}$. Following Mehra and Prescott (1985) we restrict values for ρ to be less than 10;[23] as a starting point we take $\rho = 5$. We choose GDP per capita in the rich region to be 50% higher than in the poor region, implying $\mu = 0.6$. This is reasonable: using data of 1996, in Italy GDP per capita in the North was 79% higher than in the South; in Spain the East had an advantage of 53% over the South; and in Belgium the difference was of 29% between the North and the South (Eurostat, 2000). U.S. figures are similar: in 1998 GSP per capita in Massachusetts stood 72% above that of Mississippi (Bureau of Economic Analysis).

We normalize $A = 1$ and set $\widehat{A} = 1.1$. Comparing the South adopting the new technology with the North adopting the new technology, these figures imply an annual real productivity growth rate over a period of 25 years which is on average 1.6 percentage points higher in the South. This is roughly in line with differences in TFP growth rates across countries (Young, 1995). For the new technology's initial productivity in the South we take $a^* = 0.7$; this implies an annual productivity increase of around 2% if the South adopts the new technology.

Following standard practice, we assume an annual real interest rate of 4%, which leads to an annual discount factor of around 0.96. If we think of new technologies arising once every 25 years, this gives a value for β of 0.375. Finally, for want of a specific prior, we set the probability of the North adopting the new technology $p = 0.5$.

Column (6) in Table 1 gives the set of redistribution policies Γ^{RU} consistent with rational underdevelopment. In the baseline case rational underdevelopment occurs for transfers that reduce the North's relative income from 1.5 to a level ranging from 1.218 to 1.312. This corresponds to a 38% to 56% decrease in regional inequality. This reduction in inequality is substantial, though not unusual. Estimates for Canadian provinces in the

[23] Kandel and Stambaugh (1991) claim that larger values of ρ should not be ruled out. See Campbell (1999) for a summary of the empirical literature on the coefficient of risk aversion.

1980s find a figure of 44% (Bayoumi and Masson, 1995).[24] The two extremes of our range of redistribution policies have an easy interpretation: 1.218 corresponds to the maximum level of redistribution acceptable to the North; and 1.312 corresponds to the minimum level of redistribution acceptable to the South. Column (7) in Table 1 gives the tax rates in the North required to finance redistribution: to limit relative income to 1.218 we need a tax rate of 8.5% in the North; to limit relative income to 1.312 that tax rate drops to 5.4%.

Table 1: Rational underdevelopment for different parameter values

(1) Risk aversion ρ	(2) Discount factor β	(3) New techn. $\widehat{A}$	(4) North adopts p	(5) Productivity South a^*	(6) Rational underdev't $\Gamma^{RU}[\alpha_1, \alpha_2]$	(7) Tax rate North $[\frac{t}{w}(\alpha_1), \frac{t}{w}(\alpha_2)]$
1. Baseline case						
5	0.375	1.10	0.5	0.7	**1.218, 1.312**	0.085, 0.054
2. Risk aversion						
9	0.375	1.10	0.5	0.7	**1.128, 1.338**	0.117, 0.046
3	0.375	1.10	0.5	0.7	**1.284, 1.292**	0.063, 0.061
2	0.375	1.10	0.5	0.7	**- -**	- -
3. Discount factor						
5	**0.3**	1.10	0.5	0.7	**1.251, 1.324**	0.074, 0.050
5	**0.4**	1.10	0.5	0.7	**1.208, 1.309**	0.088, 0.055
4. Productivity of new technology						
5	0.375	**1.2**	0.5	0.7	**1.269, 1.307**	0.068, 0.056
5	0.375	**1.4**	0.5	0.7	**- -**	- -
4. Probability of North adopting						
5	0.375	1.10	**0.6**	0.7	**1.251, 1.327**	0.071, 0.050
5	0.375	1.10	**0.4**	0.7	**1.181 1.299**	0.097, 0.058
5. Initial productivity in South						
5	0.375	1.10	0.5	**0.67**	**1.218, 1.411**	0.085, 0.025
5	0.375	1.10	0.5	**0.73**	**1.218, 1.224**	0.085, 0.083

[24] This is an upper bound.

As a robustness check, and to gain further insight into the role of the different parameters, we now look at some variations of the baseline case. As expected, higher risk aversion increases the range of redistribution policies consistent with rational underdevelopment. At greater levels of risk aversion the North is willing to pay higher transfers to remain in the lead; and the South is ready to accept lower transfers, since staying backward becomes more costly.

Changing the discount factor has contrary effects in North and South. A smaller discount rate increases the relative importance of the first period, so that the North wants less redistribution (since it is worried about insuring itself in the second period) and the South wants more redistribution (since it is the poor region in the first period).

Greater technological progress makes rational underdevelopment less likely. Rational underdevelopment occurs when the South foregoes the chance of adopting the new technology in exchange for transfers. This stance becomes more costly for the South if the new technology's productivity gain is large. In that case also the North becomes less likely to underwrite Southern backwardness: if productivity gains are substantial, the North actually gains from the South adopting the new technology.

Not surprisingly, varying the probability of the new technology locating in the North has an asymmetric effect on both regions. As it becomes more likely for the North to adopt the new technology, the South wants more insurance, and the North wants less. Finally, increasing the initial productivity of the new technology in the South limits the possibility of rational underdevelopment; it now takes bigger transfers from the North to convince Southern workers not to switch to the new technology.

All of this suggests that rational underdevelopment is more probable if risk aversion is relatively high, and if the new technology's productivity gains are relatively limited. This does not imply choosing unreasonably high risk aversion or unrealistically low productivity gains though. As shown by the examples in Table 1, rational underdevelopment is consistent with a range of plausible parameter values.

5 Concluding remarks

In this paper we have proposed a model that explains rational underdevelopment. Fiscal transfers raise wages in the backward region, thus reducing its chances to attract new technologies and take off. With high enough transfers, the backward region is sure to remain backward. If this situation is stable, we have rational underdevelopment: the leading region pays transfers to make sure it remains in the lead, and the lagging region accepts those transfers because it is not sure to benefit from the new technology.

Though we have focused on the specific case of wage subsidies, we have argued that our result is much more general. Public employment, lumpsum transfers, and unemployment benefits would all lead to similar outcomes. Of course there are other policy instruments more likely to benefit backward regions. The European Union's structural funds, which subsidize infrastructure and human capital, might be an example. However, our model suggests that such transfers may be unsustainable, because it is unclear what the richer regions gain from such an arrangement.

As a final remark, note that we have not specified how regions agree on a particular level of redistribution α. Our objective has been to delimit a set of Pareto superior redistribution policies consistent with rational underdevelopment, without saying how to pick a unique policy from that set Γ^{RU}. This leaves room for political conflict about the size of inter-regional transfers: within Γ^{RU} the poor region will want high levels of redistribution, and the rich region will want low levels of redistribution. Whichever rule is applied to resolve this conflict though, it will not affect our result: any policy chosen from Γ^{RU} leads to rational underdevelopment.

Appendix

A Time consistency

In this section we show that our simple time-inconsistent two-period model can easily be thought of as a time-consistent infinite horizon model. To do so, we take a simple overlapping generations approach. Agents live for two periods: in the first period the agent is a "child", and in the second period the agent becomes an "adult". Adults in period t care about consumption in periods t and $t+1$; in other words, they worry about their own and their children's consumption. Only adults take part in the decision process determining the level of transfers.

In each period a new manufacturing technology is introduced (but not necessarily adopted). Starting at a level A_1 in period 1, the rate of technological progress in manufacturing is either θ — if one of the regions adopts the new technology — or zero — if neither region adopts the new technology:

$$A_t = \begin{cases} (1+\theta)A_{t-1} & \text{if in } t \text{ the new technology is adopted} \\ A_{t-1} & \text{if in } t \text{ the new technology is not adopted} \end{cases} \tag{32}$$

where A_t is manufacturing productivity in t.[25] The poor region's initial productivity in the new technology follows a similar time-path. Starting at a level a_1^* in period 1, we have:[26]

$$a_t^* = \begin{cases} (1+\theta)a_{t-1}^* & \text{if in } t-1 \text{ the new technology was adopted} \\ a_{t-1}^* & \text{if in } t-1 \text{ the new technology was not adopted} \end{cases} \tag{33}$$

Assume v in (5) is a CRRA utility function. In period 1 the utility functions of the rich and the poor region are then:

$$U_1(\alpha) = v(\frac{\alpha}{1+\alpha}A_1^\mu) = \frac{(\frac{\alpha}{1+\alpha}A_1^\mu)^{1-\rho}}{1-\rho} \tag{34}$$

$$U_1^*(\alpha) = v(\frac{1}{1+\alpha}A_1^\mu) = \frac{(\frac{1}{1+\alpha}A_1^\mu)^{1-\rho}}{1-\rho} \tag{35}$$

For all subsequent periods, the utility functions are defined recursively. For instance, in period t, assuming the new technology is adopted, the utility function of the rich region can be written as:

$$\begin{aligned} U_t(\alpha) &= v(\frac{\alpha}{1+\alpha}A_t^\mu) \\ &= \frac{(\frac{\alpha}{1+\alpha}A_t^\mu)^{1-\rho}}{1-\rho} \\ &= (1+\theta)^{\mu(1-\rho)}\frac{(\frac{\alpha}{1+\alpha}A_{t-1}^\mu)^{1-\rho}}{1-\rho} \\ &= f(\theta)U_{t-1}(\alpha) \end{aligned}$$

[25] The model in this paper only studies two periods: manufacturing productivity in period 1 is A, and manufacturing productivity in period 2 is either A (if the new technology is not adopted) or $\widehat{A}$ (if the new technology is adopted).

[26] Because of leapfrogging the poor region in period t need not be the same region as the poor region in period $t-1$. We therefore slightly change the notation: variables with an asterisk "*" now refer to the "poor" region, rather than the "South"; and variables without an asterisk refer to the "rich" region, rather than the "North".

But of course the new technology is not always adopted, so that the full expression of the rich region's utility function in t is:

$$U_t(\alpha) = \begin{cases} f(\theta)U_{t-1}(\alpha) & \text{if in } t \text{ the new technology is adopted} \\ U_{t-1}(\alpha) & \text{if in } t \text{ the new technology is not adopted} \end{cases} \tag{36}$$

In a similar way the utility function of the poor region in t is:

$$U_t^*(\alpha) = \begin{cases} f(\theta)U_{t-1}^*(\alpha) & \text{if in } t \text{ the new technology is adopted} \\ U_{t-1}^*(\alpha) & \text{if in } t \text{ the new technology is not adopted} \end{cases} \tag{37}$$

In period 1 the problem is identical to the two-period model described in the text. It suffices to realize that in period 1 the discounted sum of expected utility in the rich and the poor region are given by (26)-(31):

$$U(\alpha) = \begin{cases} U_1(\alpha) + \beta[pU_{2h}(\alpha) + (1-p)U_{2y}(\alpha)] & \text{if } \alpha \in \Gamma^c \\ U_1(\alpha) + \beta[pU_{2h}(\alpha) + (1-p)U_{2n}(\alpha)] & \text{if } \alpha \in \Gamma \end{cases} \tag{38}$$

$$U^*(\alpha) = \begin{cases} U_1^*(\alpha) + \beta[pU_{2h}^*(\alpha) + (1-p)U_{2y}^*(\alpha)] & \text{if } \alpha \in \Gamma^c \\ U_1^*(\alpha) + \beta[pU_{2h}^*(\alpha) + (1-p)U_{2n}^*(\alpha)] & \text{if } \alpha \in \Gamma \end{cases} \tag{39}$$

In period 1 we choose α for period 1 and period 2 following a certain decision rule.[27] Assume this decision rule is invariant to affine transformations of the utility functions; i.e., if we multiply the utility functions of both regions by a constant, the α chosen does not change. In period 2 the new technology is or is not adopted, depending partly on the α chosen in period 1. The question is now whether our decision of period 1 is time-consistent: is the α chosen in period 1 still optimal in period 2? The answer is yes. There is no reason to re-negotiate the level of redistribution in period 2. To see this, we distinguish between two cases, depending on whether or not the new technology has been adopted.

Start off by supposing the new technology has been adopted. In that case utility in the rich region and utility in the poor region are given by $f(\theta)$ times utility in (38) and (39). Note furthermore that, following (33), condition (20) is unchanged. This implies that the utility ordering is unchanged too, so that the decision problem in period 2 is identical to the one in period 1; the α chosen in period 1 is therefore time-consistent. Now suppose, instead, that the new technology has not been adopted. In that case the conclusion is even more straightforward, since utility in the rich region and utility in the poor region coincide with (38) and (39). The decision problem is unchanged, so that the α chosen in period 1 is time-consistent. It is clear that the same argument can be applied in all subsequent periods.

[27] Note that in our discussion of rational underdevelopment we focused on the range of Pareto superior transfer policies, without specifying a decision rule for choosing one particular α from that range. One example of a possible decision rule would be Nash bargaining.

B Proof of Theorem 1

Let Ω be the set of possible redistribution schemes, i.e. $\Omega = [1, \frac{\mu}{1-\mu}]$. In the second period the South adopts the new technology if

$$\alpha > \frac{A}{\mu a^*} - 1$$

To simplify the notation we drop through this appendix "$*$" and write a instead of a^*. Let $\alpha(a) \equiv \frac{A}{\mu\, a} - 1$. Thus the function $\alpha(a)$ gives the level of redistribution that makes the South indifferent between adopting the new technology and continuing to produce exclusively food. The set of redistributive policies for which the South does not adopt the new technology is:

$$\Gamma(a) \equiv \{\alpha \in \Omega : \alpha \leq \alpha(a)\} = [1, \alpha(a)]$$

Sometimes we just write Γ. Let $\Gamma^c(a) \equiv \Omega/\Gamma(a)$, i.e., $\Gamma^c(a)$ is the set of α for which the South adopts the technology. This set is also an interval of the form $\left]\alpha(a), \frac{\mu}{1-\mu}\right]$ Sometimes we write it as Γ^c. Recall that the expressions for the expected utilities were given by

$$U(\alpha) = \begin{cases} U_y(\alpha) & \text{if } \alpha \in \Gamma^c \\ U_n(\alpha) & \text{if } \alpha \in \Gamma \end{cases}$$

$$U^*(\alpha) = \begin{cases} U_y^*(\alpha) & \text{if } \alpha \in \Gamma^c \\ U_n^*(\alpha) & \text{if } \alpha \in \Gamma \end{cases}$$

These functions are continuous everywhere in Ω except possibly at $\alpha(a)$ (see Figure 2). The strategy of the proof consists in showing that we can generate a situation similar to the one in Figure 2.

Step 1. $U_n(\alpha)$ is strictly increasing and $U_n^*(\alpha)$ is strictly decreasing.

$U_n(\alpha)$ is given by

$$v\left(\frac{\alpha}{1+\alpha}A^\mu\right) + \beta\left[p\ v\left(\frac{\alpha}{1+\alpha}\widehat{A}^\mu\right) + (1-p)\, v\left(\frac{\alpha}{1+\alpha}A^\mu\right)\right]$$

which is, clearly, strictly increasing in α. $U_n^*(\alpha)$ is given by

$$v\left(\frac{1}{1+\alpha}A^\mu\right) + \beta\left[p\ v\left(\frac{1}{1+\alpha}\widehat{A}^\mu\right) + (1-p)\, v\left(\frac{1}{1+\alpha}A^\mu\right)\right]$$

which is, clearly, strictly decreasing in α.

Step 2. We will construct a set $P \subset \Gamma$ of redistribution policies that are preferred by the

Figure 3:

North to any policy in Γ^c. (See Figure 3).

i) For $\overline{a} \equiv \frac{A(1-\mu)}{\mu}$ we have $\Gamma(\overline{a}) = [1, \frac{1-\mu}{\mu}]$, i.e., the new technology is never adopted.

ii) We have

$$U_n\left(\frac{\mu}{1-\mu}\right) = u\left(\mu\, A^{\mu}\right) + \beta\, \left[p\, u\left(\mu\, \widehat{A}^{\mu}\right) + (1-p)\, u\, \left(\mu\, A^{\mu}\right)\right]$$

and

$$U_y\left(\frac{\mu}{1-\mu}\right) = u\left(\mu\, A^{\mu}\right) + \beta\, \left[p\, u\left(\mu\, \widehat{A}^{\mu}\right) + (1-p)\, u\, \left((1-\mu)\, \widehat{A}^{\mu}\right)\right]$$

so that $U_n\left(\frac{\mu}{1-\mu}\right) > U_y\left(\frac{\mu}{1-\mu}\right)$ iff $p < 1$, $\beta > 0$ and $\frac{\mu}{1-\mu} > \left(\frac{\widehat{A}}{A}\right)^{\mu}$. This corresponds to Condition 1 and Condition 2, so that $U_n(\frac{\mu}{1-\mu}) > U_y(\frac{\mu}{1-\mu})$.

iii) By the previous two points and by continuity of U_n, U_y, and $\alpha(a)$, there exists $\widetilde{a} > \overline{a}$ close enough to $\overline{a}$ such that $U_n(\alpha(\widetilde{a})) > U_y(\alpha)$ for all $\alpha \in [\alpha(\widetilde{a}), \frac{\mu}{1-\mu}]$.

iv) Let $z = \max_{\alpha \in [\alpha(\widetilde{a}), \frac{\mu}{1-\mu}]} U_y(\alpha)$. By continuity of $U_y(\alpha)$ the value z is well defined. Let $\underline{\alpha}(\widetilde{a})$ be the solution to

$$z = U_n(\alpha)$$

and if $z < U_n(\alpha)$ for all $\alpha \in \Omega$ we set $\underline{\alpha}(\widetilde{a}) = 1$. Since $U_n(\alpha)$ is strictly increasing $\underline{\alpha}(\widetilde{a})$ is well defined.

Let $P(\widetilde{a}) \equiv \{\alpha : \underline{\alpha}(\widetilde{a}) \leq \alpha \leq \alpha(\widetilde{a})\}$. By construction $P(\widetilde{a}) \subset \Gamma(\widetilde{a})$. Moreover, $P(\widetilde{a})$ is non-empty; to see this, it suffices to show that $\underline{\alpha}(\widetilde{a}) < \alpha(\widetilde{a})$; this is immediate, given that $U_n(\alpha)$ is strictly increasing and given that $U_n(\alpha(\widetilde{a})) > U_y(\alpha)$ for all $\alpha \in [\alpha(\widetilde{a}), \frac{\mu}{1-\mu}]$. It is also clear that for any $\alpha \in P(\widetilde{a})$ we have $U_n(\alpha) \geq U_y(\alpha')$ for all $\alpha' \in \Gamma^c(\widetilde{a})$. Thus, the transfer schemes in $P(a)$ are Pareto superior for the North to the transfers schemes for which the South adopts the new technology. Notice that the North is (weakly) better off under $\alpha \in P(\widetilde{a})$ than under zero transfers, i.e. all the policies in $P(\widetilde{a})$ are also individually rational for the North.

Recall that $\widehat{\alpha}$ satisfies $U_n(\widehat{\alpha}) = U_y(\frac{\mu}{1-\mu})$. It is not difficult to see that for a small enough the value $\alpha(a)$ approaches to $\frac{\mu}{1-\mu}$ and $\underline{\alpha}(a)$ approaches to $\widehat{\alpha}$ (see Figure 3), i.e.:

$$Lim_{a \to \left(\frac{A(1-\mu)}{\mu}\right)^+} \quad \underline{\alpha}(a) = \widehat{\alpha}$$

and

$$Lim_{a \to \left(\frac{A(1-\mu)}{\mu}\right)^+} \quad \alpha(a) = \frac{\mu}{1-\mu}$$

The idea is simple, when a approaches (from right) its lowest possible value, the South almost never adopts the new technology and the set $P(a)$ approaches the set of all $\alpha's$ such that $U_n(\alpha) > U_y(\frac{\mu}{1-\mu})$, and the lower bound of this set is $\widehat{\alpha}$ and the upper bound is $\frac{\mu}{1-\mu}$. Given that $\widehat{\alpha} < \underline{\alpha}(\widetilde{a})$ and $\frac{\mu}{1-\mu} > \alpha(\widetilde{a})$, and given that $P(\widetilde{a})$ is non empty, it is clear that for a small enough, $P(a)$ is non empty.

Step 3. We will construct, in a parallel way to what we did in Step 2 for the North, a set $P^* \subset \Gamma$ of redistribution policies that are preferred by the South to any policy in Γ^c. (See Figure 4).

i) Condition 3 implies that $U_n^*(1) > U_y^*(\frac{\mu}{1-\mu})$. Step 1 showed that $U_n^*(\alpha)$ is strictly decreasing in α. Hence, and by continuity of U_n^*, U_y^*, and $\alpha(a)$, there exists $a' > \overline{a} \equiv \frac{A(1-\mu)}{\mu}$ close enough to $\overline{a}$ such that $U_n^*(1) > U_y^*(\alpha)$ for all $\alpha \in [\alpha(a'), \frac{\mu}{1-\mu}]$.

ii) Let $z = \max_{\alpha \in [\alpha(a'), \frac{\mu}{1-\mu}]} U_y^*(\alpha)$. By continuity of $U_y^*(\alpha)$ the value z is well defined. Let $\overline{\alpha}(a')$ be the solution to

$$z = U_n^*(\alpha)$$

Since $U_n^*(\alpha(a')) < U_y^*(\alpha(a'))$, since $U_n^*(\alpha)$ is strictly decreasing, and since $U_n^*(1) > z$, we can conclude that $\overline{\alpha}(a')$ is well defined.

Let $P^*(a') \equiv \{\alpha : 1 \leq \alpha \leq \overline{\alpha}(a')\}$. By construction $P^*(a') \subseteq \Gamma(a')$. Moreover, $P^*(a')$ is non empty; to see this, it suffices to show that $\overline{\alpha}(a') < 1$; this is immediate, given

Figure 4:

that $z < U_n^*(1)$. It is also clear that for any $\alpha \in P^*(a')$ we have $U_n^*(\alpha) \geq U_y^*(\alpha')$ for all $\alpha' \in \Gamma^c(a')$. Thus, the transfer schemes in $P^*(a)$ are Pareto superior for the South to the transfers schemes for which the South adopts the new technology. Notice that the South is (weakly) better off under $\alpha \in P^*(a')$ than under zero transfers, i.e. all the policies in $P(a')$ are also individually rational for the South. Recall that $\widehat{\alpha}^*$ satisfies $U_n^*(\widehat{\alpha}^*) = U_y^*(\frac{\mu}{1-\mu})$. It is not difficult to see that for a small enough the value $\alpha(a)$ approaches $\frac{\mu}{1-\mu}$ and $\overline{\alpha}(a)$ approaches to $\widehat{\alpha}^*$ (see Figure 4), i.e.:

$$Lim_{a \to \left(\frac{A(1-\mu)}{\mu}\right)^+} \ \overline{\alpha}(a) = \widehat{\alpha}^*$$

Given that $\widehat{\alpha}^* > \overline{\alpha}(a')$ and given that $P^*(a')$ is non empty, it is clear that for a small enough the set $P^*(a)$ is non empty.

Step 4 We want to show that for a small enough the set $R(a) \equiv P(a) \cap P^*(a)$ is not empty. Remember that $P(a)$ is given by the interval $[\underline{\alpha}(a), \alpha(a)]$ and $P^*(a)$ is given by the interval $[1, \overline{\alpha}(a)]$, and for a small enough those intervals are not empty: We showed that $Lim_{a \to \left(\frac{A(1-\mu)}{\mu}\right)^+} \ \underline{\alpha}(a) = \widehat{\alpha}$ and $Lim_{a \to \left(\frac{A(1-\mu)}{\mu}\right)^+} \ \overline{\alpha}(a) = \widehat{\alpha}^*$. Thus, for a small enough, $R(a)$ is not empty if $\widehat{\alpha} < \widehat{\alpha}^*$, and this inequality is just Condition 3. Since $R(a) \subseteq \Gamma^{RU}(a)$ we have that, for a small enough, $\Gamma^{RU}(a)$ is not empty, and this concludes the proof.

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