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Positive Feedback Mechanisms in Economic Development: A Review of Recent Contributions

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This chapter presents a very selective review of recent attempts to explain the stylized facts of economic development with models that exhibit multiple Pareto-rankable equilibria and path dependence. In essence, this literature explains lack of growth as a result of "vicious circles of poverty": either the economy is at a "bad" equilibrium or its initial conditions are such that there is no equilibrium path along which the economy can move towards an "advanced" steady state. This literature stands in stark contrast to the more standard tradition in economics, which holds that lack of growth is the result of poorly functioning economic institutions and incorrect policies.

The main ingredient of this new literature is externalities. It is well known that when externalities (that are not internalized) arise, the allocation of resources is not optimal. As a result, many people have argued that the government should intervene to alter the allocation of resources, favouring those industries (and more generally those activities, for example, education) that generate positive externalities. Stated this way, however, this argument is equally relevant for industrial and developing countries and thus does not seem particularly important for development policy.

When several economies are inter-dependent through trade or factor flows, these externalities—if they are strong enough and geographically limited—may have more drastic effects: they may lead to geographic concentration of economic activity, multiple Pareto-rankable equilibria (that is, a bad and a good equilibrium) and underdevelopment traps (that is, a situation in which the only equilibrium path involves no long-run growth). In other words, such externalities may lead to a situation in which the countries of the "North" produce "sophisticated" goods that generate important positive externalities, whereas the "South" remains trapped, specializing in "slow", "simple" or "backward" goods that entail no such externalities. As a consequence, the North may exhibit continuous growth and pay higher wages for similar types of labour than the South—and allowing for capital flows will not lead to convergence.

Whether externalities lead to agglomeration economies, multiple equilibria and poverty traps depends on whether they generate positive feedback mechanisms (also called self-reinforcing mechanisms). Recall that the basic neoclassical general-equilibrium model, with its standard convexity assumptions, entails negative feedback mechanisms. For instance, an increase in production leads to a higher marginal cost and a lower price, discouraging further output increases. Externalities are introduced into the neoclassical model usually without changing this basic property: the economy remains convex, only now some markets are missing, preventing Pareto optimality. For instance, an increase in production may lead to lower marginal costs when externalities are sufficiently strong, but it is assumed that the decrease in price is sufficient to offset this decline, so that, again, further output increases are discouraged. In contrast, recent models of economic development assume that such dampening forces are not sufficiently strong. These models thus feature positive feedback mechanisms.

Economists today believe that externalities may be important for at least two reasons. First, most contributions to the new endogenous growth literature attempt to explain the persistence of growth by assuming the existence of aggregate externalities. Second, some

recent papers show that increasing returns to scale at the level of the firm may lead to industry-wide (pecuniary) externalities. Hence, the technological or non-pecuniary externalities (such as information spillovers) with which many economists are uncomfortable because of their "invisible" and abstract nature are not necessary to generate the kind of phenomena discussed above (although some sort of non-tradability becomes a necessary assumption). More importantly, assuming increasing returns to scale at the level of the firm has proved very useful in growth theory (to model innovation), in macroeconomic theory (to understand business cycles) and in trade theory (to understand intra-industry trade), leading to the widespread belief that this assumption is warranted.

The ideas that I will review in this chapter have been around at least since the 1950s and 1960s, when they had a strong impact on development policy. But as Krugman (1992) has pointed out, these ideas were not properly formalized and not well understood until recently, when we learned how to work with models that involve increasing returns to scale. Still, the fact that development policies based on those ideas (such as import substitution, investment subsidies, government enterprise) failed dramatically (see Little, 1982) makes one somewhat skeptical about the value of considering these ideas again. I believe there are at least two reasons why we should. First, the ability to capture those old ideas in formal models has led to a better understanding of the conditions under which government intervention may be warranted and the kind of information that would be necessary to carry out such intervention successfully. Second, past policy failures do not constitute proof that these models are empirically irrelevant: those policies could have failed because government institutions were not designed appropriately to carry them out.

The following section of the chapter discusses the stylized facts of economic development to gauge whether we should move beyond the neoclassical growth model, which predicts the existence of "automatic" development mechanisms. The third section discusses some general issues concerning models with externalities and positive feedback mechanisms, and the three sections following discuss particular models in which externalities lead to multiple equilibria or path dependence. The final section concludes with some general lessons for development policy.

I should mention that this chapter will not review the extensive literature on the development experience of particular countries nor the literature on how industrial policy has succeeded or failed in practice (see Little, Scitovsky and Scott 1970; Little 1982; Rodrik 1993; and World Bank 1993 for reviews of these issues). This chapter will also abstract from issues of income distribution and from political economy considerations, such as whether informed politicians are likely to intervene for society's benefit or for their own benefit.

THE NEOCLASSICAL GROWTH MODEL AND ECONOMIC DEVELOPMENT

Should we be interested in models with multiple equilibria or poverty traps? Should we abandon the neoclassical growth model, which predicts that automatic mechanisms will pull an economy out of economic underdevelopment? The neoclassical growth model explains underdevelopment as a consequence of capital scarcity. Accordingly, the rate of return to capital should be high in poor countries, generating strong incentives for foreign investment and domestic capital accumulation. Yet a casual look at the experience of many developing economies since World War II questions whether these automatic development mechanisms exist: in many poor economies per capita income has remained stagnant for decades and both foreign and domestic investment have been relatively low as a percentage of total production.

Moving beyond casual empiricism, Barro (1991) and Barro and Sala-i-Martin (1992) consider whether the neoclassical prediction of convergence of per capita income is consistent with the data. The first finding is that there is no convergence for the whole set of countries, that is, poorer countries are not growing faster than rich countries. In fact, Barro (1991) shows that there is a mild tendency for divergence—there is a mild positive correlation between initial income per capita and subsequent growth.

Barro then introduces the concept of conditional convergence, which modifies the concept of convergence to allow for the possibility that different countries have different steady states. That is, conditional convergence implies that countries that are further away from their own steady states grow at a faster rate than countries that are close to their steady states.[1] Barro confirms the existence of conditional convergence for the whole set of countries. Taking 1960 school enrollment rates as proxies for steady states (that is, countries with high 1960 school enrollment rates have high steady-state incomes per capita), conditional convergence implies that, holding school enrollment rates fixed, countries with a lower initial income per capita should have had higher subsequent growth. Barro verifies this claim by showing a negative partial correlation between the growth of income per capita in 1960–85 and income per capita in 1960. This finding provides one explanation for the absence of convergence: poorer countries need not grow faster than rich countries because their poverty is associated with a lower income per capita steady state, as reflected in lower school enrollment rates. This result of conditional convergence is consistent with the view advanced by Durlauf and Johnson (1992), who argue that different countries are converging to different steady states: there is convergence among subgroups of similar countries, but dissimilar countries may be diverging.

One problem with the conditional convergence approach is that it takes initial school enrollment rates as exogenous. It would seem more natural to regard school enrollment rates as private decisions based on future growth prospects. In this case, as shown in Bils and Klenow (1995), school enrollment rates would be higher in countries with higher growth prospects. Thus we could interpret the previous results as implying that countries that (for some reason) have better future growth prospects have higher initial school enrollment rates. In fact, Bils and Klenow find that this possibility is more plausible than the usual interpretation of the positive correlation between initial school enrollment rates and subsequent growth—that is, they find that the data are more consistent with the view that schooling responds to future growth prospects rather than the view that schooling drives growth.

A second and more important limitation of the conditional convergence approach as a way to think about economic development is that it does not explain why countries have significantly different steady state income per capita levels. Is not this precisely the puzzle that we are trying to solve? In fact, as suggested recently by Islam (1995), such differences in steady state income per capital levels may be almost as large as the differences in the levels observed in the data.

According to the neoclassical model such differences in steady state income per capita levels are a result of differences in taxes on capital. As opposed to rich countries, poor countries have high (implicit and explicit) taxes on returns to capital, decreasing the capital stock per worker in steady state and consequently also decreasing income per capita. The problem with this explanation is that unreasonably high taxes in poor countries would be necessary to generate the large observed disparity in income per capita levels between poor and rich countries. For instance, assuming a Cobb-Douglas production function with physical capital and labour, and a capital share of 0.4 (which implies that capital holders receive 40 per cent of total income), the implied marginal tax on capital returns for a country with an income per capita level of one-tenth the US level would be 98 per cent.[2] The corresponding pre-tax rate of return to capital would be 32 times higher in the poor country than in the United States.

These numbers become more reasonable if it is assumed that the share of capital in total income is higher than 40 per cent. A capital share of two-thirds may be appropriate if we consider human capital as another reproducible factor in addition to physical capital, as is done, for instance, by Mankiw, Romer and Weil (1992) and Chari, Kehoe and McGrattan (1995). In this case the implied marginal tax on capital would be 77 per cent, and the pre-tax rate of return to capital would be three times higher in the poor country than in the United States. These are certainly more reasonable numbers. Of course, we do not observe tax rates of 77 per cent on capital in poor countries, but macroeconomic instability, barriers to trade, weak enforcement of property rights, corruption and even possibly war have a similar effect to taxes in reducing income.

It thus appears that, once modified to take into account human capital, the neoclassical model is consistent with the empirical evidence. The view that emerges from this new version of the neoclassical model is that countries that adopt the right set of economic policies will converge towards the income levels of rich countries.[3] This is consistent with the view advanced by Sachs and Warner (1995), who find an "overwhelming tendency towards convergence" for countries that "have followed standard market-based economic policies, including respect for private property rights and open international trade." This is true "even among countries that start with extremely low levels of human capital endowments and extremely low levels of initial per capita income" (p. 6).[4]

This is not the only possible interpretation of the evidence, however. One could argue instead that the lack of convergence is due to the fact that some countries are caught in a low-level equilibrium or are stuck in a poverty trap. There is virtually no empirical research on the question of whether this "bad luck" story is more or less plausible than the "bad policy" story advocated by economists closer to the neoclassical paradigm. Thus the rest of the chapter simply explores the "bad luck" view and the associated policy implications.

EXTERNALITIES AND POSITIVE FEEDBACK MECHANISMS

I will now review some models that exhibit externalities and positive feedback mechanisms, and consider how they can explain three important stylized facts of economic development: no absolute convergence, the richest and poorest countries are growing at the same rate (Parente and Prescott, 1993) and the existence of "economic miracles", that is, countries that in a few decades have gained membership into the club of rich countries—for example, Hong Kong, the Republic of Korea, Singapore and Taiwan (province of China).

The second fact implies that if we want to consider models with poverty traps as an explanation for the lack of convergence, then we must assume that there are at least two sources of growth: one that is relevant for the long run and applies to all countries (that is, technical change that diffuses to all countries) and one that has to do with catching-up or convergence. In this light a poverty trap is relative—it implies that it may be very difficult for countries with the lowest incomes per capita to catch up to the countries with the highest.

Models with externalities and positive feedback mechanisms explain economic miracles as instances in which an economy jumps from a bad to a good equilibrium. Such a jump would imply a significant increase in the value of production with an unchanged quantity of resources, leading to a high predicted rate of total factor productivity growth over the period in which the miracle occurs. Some economists have agreed that this prediction is inconsistent with Young's (1995) careful estimates of total factor productivity growth for the Asian miracles—Hong Kong, the Republic of Korea, Singapore and Taiwan (province of China). In fact, as argued in detail in Klenow and Rodríguez-Clare (1996), Young's estimates are entirely consistent with the view that the east-Asian miracle was driven primarily by increases in total factor productivity (except in the case of Singapore).

What do we know about the empirical relevance of externalities and the positive feedback mechanisms that they may generate? The existence of cities and regional concentrations of economic activity are an important confirmation of the empirical importance of such positive feedback mechanisms. Furthermore, as Porter (1992) and Krugman (1991) have shown, related economic activity is often geographically concentrated, like high-tech industries in Silicon Valley and along Boston Route 128, fur products in New York and ceramic tiles in Sassuolo, Italy (see also Henderson, 1988).

At a more formal level Ellison and Glaeser (1994) show that the observed geographic concentration of industries is greater than what we would expect to see if location choice was purely random. This occurs even for "footloose" industries, suggesting the existence of significant localized externalities. Furthermore, Ciccone and Hall (1996) show the existence of significant positive density externalities—that is, they find that, other things being equal, firms operating in areas that are economically dense are more productive than firms operating in relative isolation.

AGGREGATE DEMAND SPILLOVERS

Positive externalities may arise from aggregate demand spillovers if production is carried out under decreasing average costs. This basic idea was formulated by Rosenstein-Rodan (1943) with his famous shoe factory example: the wages that factory workers earn making shoes are spent not only on shoes but also on other manufactures and agricultural goods. As a consequence, an entrepreneur will not want to start up shoe production in a poor economy because demand is not sufficient to make such investment profitable. Yet if other entrepreneurs simultaneously invest in other industries, the argument goes, then enough demand may be generated to make all investments profitable. For this story to be relevant it is crucial that industrial production be characterized by decreasing average costs, because it is this feature that makes profitability depend on aggregate demand.

Murphy, Shleifer and Vishny (1989) have recently formalized this argument. Because their paper has been extremely influential in reviving interest in models with externalities and multiple equilibria, it is worth describing it in some detail. In their model the economy is closed to international trade in all goods, and there are two technologies used to produce every good: cottage production and modern technology. Cottage production is characterized by constant average costs, while the modern technology entails a fixed production cost and a marginal cost that is lower than that of cottage production. If an entrepreneur decides to invest in the modern technology to produce a particular good, then he can undercut the competition from cottage production, which produces with higher average costs. He can thus charge a mark-up over costs. But given the fixed start-up cost, the profitability of his investment depends on market size, or aggregate demand. And aggregate demand depends on the purchasing power of workers, which depends in turn on the extent of industrialization (that is, how widespread the use of the modern technology is). This circularity leads to the possibility of multiple equilibria. In the "no-industrialization" equilibrium demand remains small, industrialization does not take place, income per capita is low and hence demand remains small. In contrast, the industrialization equilibrium entails high aggregate demand, which makes industrialization profitable. Industrialization leads to high aggregate income and high aggregate demand for each manufactured good.

Interestingly, Murphy, Shleifer and Vishny find that the conditions necessary for multiple equilibria are more stringent than those loosely expressed in much of the "big-push" literature. In particular, they find that the aggregate demand spillovers that generate multiple equilibria are not the ones that arise as the profits made in one sector are spent on goods made in other sectors. To see this, notice that in order to generate multiple equilibria, industrialization must be individually unprofitable at the bad equilibrium but individually profitable when several other sectors industrialize. If a firm makes negative profits at the no-industrialization equilibrium, however, then it does not contribute to aggregate income. In fact, by decreasing aggregate income, the firm makes it even less profitable to invest in the modern technology. Thus, the existence of a no-industrialization equilibrium precludes the existence of an industrialization equilibrium. See Appendix 1 for a formal derivation of this result.

Murphy, Shleifer and Vishny postulate a mechanism that is close in spirit to Rosenstein-Rodan's (1943) shoe factory parable that leads to multiple equilibria. They assume that firms producing with the modern technology have to pay a wage premium to workers above what they are paid by firms producing with the cottage technology. This obligation could be the result of poorer working conditions at modern factories or the fact that those factories are further away from where workers live. If modern factories have to pay a wage premium, then aggregate demand spillovers arise not only through profits but also through the excess wages that firms operating modern technologies must pay. Thus, starting from a situation with no industrialization, investing in the modern technology may be individually unprofitable because of low demand, yet still generate positive aggregate spillovers when the entrepreneur's losses are lower than the total wage premiums paid to workers. In this case multiple equilibria arise, and the industrialization equilibrium Pareto-dominates the no-industrialization equilibrium: workers are just as well off in the industrialization equilibrium as in

the no-industrialization equilibrium, but average income per capita is higher in the first because profits are higher.[5]

Murphy, Shleifer and Vishny mention other mechanisms that also generate multiple equilibria. For instance, if production with the modern technology takes place in the city and cottage production takes place in the rural area, and if city dwellers' demand is more concentrated on manufactures (such as textiles and furniture), then positive spillovers may still arise even with negative profits, because industrialization by some firms leads to an increase in urban population, which increases the share of income that is spent on manufactures.[6] Murphy, Shleifer and Vishny also present a dynamic model in which the start-up investment is made in one period and production in the next period. Then, a firm that makes negative profits still generates positive spillovers as it increases aggregate demand in the second period, leading to higher profits for other firms that invest in the modern technology.

Rosenstein-Rodan's big-push argument and its subsequent formalizations have been repeatedly criticized because their main results depend on the closed economy assumption. Since most modern economies are well integrated with the world market, the argument goes, there is no need to generate domestic demand for industrialization. But it is easy to respond to this criticism by arguing that the existence of transportation costs implies that firms can earn higher per-unit profits on goods sold domestically than on exports. Thus greater domestic demand does confer an advantage to domestic producers.

Krugman shows this in a model of agglomeration economies generated by aggregate demand spillovers. In Krugman's model there are two regions and two sectors: agriculture and manufacturing. Agriculture uses land, which is specific to each location—the location of agriculture is therefore exogenous. In contrast, manufacturing can take place in either location, but transporting manufactured goods involves a cost. Entrepreneurs producing manufactured goods thus have an incentive to locate close to their customers (agricultural and manufacturing workers), but they also have an incentive to service both regions from a single plant to take advantage of economies of scale. Entrepreneurs prefer to produce from a single plant located where demand is higher—and demand is higher where more entrepreneurs locate their manufacturing plants. As in the Murphy-Shleifer-Vishny model, this behaviour leads to a positive feedback mechanism, which, here, generates economies of agglomeration and geographic concentration.

Path dependence

The same forces that lead to multiple Pareto-rankable equilibria in the models mentioned so far may also lead to path dependence. This is shown by Matsuyama (1992), who introduces dynamics in the Murphy-Shleifer-Vishny model by assuming that there is some inertia in resource allocation. In particular, Matsuyama assumes that the choice of technology is partially irreversible: once an entrepreneur chooses to operate with a particular technology (cottage production or the modern technology), then he has to stick with this choice for a certain (random) length of time. Matsuyama shows that this assumption may lead to path dependence. If the economy starts near one of the two steady states (no industrialization or complete industrialization), then the only perfect-foresight path entails convergence to that steady state. This result implies that economies starting with very little industrialization are stuck in a poverty trap: even if everyone expected the economy to converge to the industrialization steady state, no entrepreneur would invest in the modern technology. Poverty in this context is thus more severe than a problem of expectations or coordination failure.

If we explain the lack of convergence with a model that features a poverty trap, we must ask how some countries were able to grow and become richer than the rest in the first place. How were some countries able to industrialize? We can think about this question in the context of Matsuyama's dynamic model, in which the existence of a poverty trap depends on certain parameters—such as country size, the inter-temporal discount rate and entrepreneurship—which Matsuyama identifies as affecting the flexibility with which entrepreneurs can reverse their past decisions. According to this model today's rich countries must have had favourable parameters that allowed them to follow an equilibrium path towards the industrialization steady state.

Evidence

What evidence do we have for the existence of aggregate demand spillovers? Unfortunately, there are not many empirical studies of this phenomenon. Caballero and Lyons (1992) is a notable exception. They show that productivity increases in all industries as overall economic activity rises. This constitutes a case of positive externalities arising from aggregate economic activity. Are these externalities due to a mechanism similar to the one behind the Murphy-Shleifer-Vishny model? Caballero and Lyons claim that the answer is no, since they find no evidence for internal increasing returns—that is, for a single industry production increases one-for-one with increases in total industry inputs. The authors argue that aggregate positive externalities arise through other mechanisms, such as thick markets (as in Diamond, 1982).

We could check the evidence for the main assumptions behind the Murphy-Shleifer-Vishny model: decreasing average costs and significant transportation costs. Because technology is endogenous, however, the existence of decreasing average costs in one economy does not rule out other options for entrepreneurs in other economies. With respect to transportation costs, the export-led development experience of the "economic miracles" of east Asia—Hong Kong, the Republic of Korea, Singapore, Taiwan (province of China)—makes it doubtful that domestic demand can be a significant obstacle to development in practice (Stiglitz, 1991).

BACKWARD AND FORWARD LINKAGES

In addition to aggregate demand spillovers, firms can also generate positive externalities to other firms more directly through their demand for and supply of inputs. This source of externalities has been discussed at least since Hirschman (1958), but not until recently has it been possible to write formal models in which properly defined linkages give rise to pecuniary externalities. The essential feature of these recent models is increasing returns to scale, which implies that not all possible goods will be produced at any point in time. The set of goods actually produced thus becomes another variable, and linkages arise as private decisions change this set.

A simple formalization of this idea is provided in Rodríguez-Clare (1996a) (based in large part on ideas from Dixit and Stiglitz, 1977; Ethier, 1982; Romer, 1990; Fujita, 1990) and presented in Appendix 2. This formalization of linkages is based on three premises: that production efficiency is enhanced by the use of a wider variety of specialized inputs, that for many of these inputs the proximity of the supplier and the user is essential, and that the size of the market limits the equilibrium variety of specialized inputs. These premises can be captured in a simple model by assuming that there is love of variety for inputs in the production of final goods (as in Ethier, 1982b; Romer, 1990), that domestic firms must buy all of their inputs locally and that inputs are produced with increasing returns to scale. Under these circumstances a firm producing final goods generates a positive externality to other final-good producers. By increasing the demand for inputs, the final-good firm helps bring forth more varieties of specialized inputs. This is our concept of backward linkages. In turn, local production of more specialized inputs enables the production of more complex goods (that is, goods that use specialized inputs with high intensity) at competitive costs. This is our concept of forward linkages.[7]

Backward linkages alone give rise to agglomeration economies, as shown by Fujita (1990). As an industry grows in a particular region, so does demand for industry-specific non-tradable inputs, giving rise to a larger variety of such inputs available locally. In other words, a larger industrial scale leads to a deeper division of labour, which in turn increases productivity. The increase in productivity then leads to a larger industry.[8]

As shown in Appendix 2, an economy that features both backward and forward linkages may exhibit multiple Pareto-rankable equilibria. In the good equilibrium the economy specializes in the production of complex goods, demand for specialized inputs is high, a large variety of these inputs is produced and wages are high. In the bad equilibrium the economy specializes in the production of simple goods (labour-intensive goods), demand for specialized inputs is low, a small variety of these inputs is produced and wages are low. In other words, when both forward and backward linkages materialize, the economy develops a deep division of labour and high wages. But such linkages may fail to materialize, in which case the economy would remain underdeveloped.[9]

Counterfactual scale effects

As with most models in which specialization is limited by the scale of the market, this model of backward and forward linkages leads to the prediction that large economies should not have a problem developing, since their large markets should be able to support a high degree of specialization. Most people immediately think of population size as the correct index for the scale of an economy and thus conclude that the low per capita incomes seen in large countries like China and India cast serious doubts on the model. But this conclusion is wrong for two reasons. First, it is not clear that the appropriate economic unit is a whole country. In the context of the model outlined above, not all provinces of a country may have access to the non-tradable inputs available in the country's economic center. It may thus be more appropriate to think about large countries such as China as a collection of differentiated economic units and not as a single integrated economy.

Second, population size may not be the appropriate measure of scale. For instance, in Rodríguez-Clare (1996a) capital is needed to produce intermediate goods, implying that an economy with a large labour force but a low capital stock will not be able to produce a large variety of non-tradable intermediate goods. Such a "large" economy would thus have a low degree of specialization.

Capital mobility

Rodríguez-Clare (1996a) shows that once we allow for international capital mobility, we can generate an equilibrium in which the rich economy (the economy at the good equilibrium) has a deep division of labour (has a large variety of non-tradable intermediate goods), specializes in the complex good and has higher wages and a higher capital-labour ratio than the poor economy (which remains at the bad equilibrium). Yet the rate of return to capital is equalized across the two economies—thus perfect international capital mobility is consistent with such an equilibrium.

Path dependence

Until now we have discussed models that feature multiple equilibria. A natural question that arises is what determines the equilibrium that is chosen. In the context of these models, we cannot say anything about this issue. But some simple alterations of these models allow us to make several interesting points.

When there are multiple equilibria, in principle all firms could coordinate and jump immediately to the good equilibrium. But this statement makes the coordination problem seem simpler than it is. As Matsuyama (1992) has argued, a static model cannot capture the difficulty of the transition to the good equilibrium. Following Matsuyama, Rodríguez-Clare (1993) introduced friction in the allocation of resources across sectors to develop a dynamic version of the model discussed above. With this version of the model we can characterize the conditions necessary for the economy to follow a path from the bad to the good steady state. If these conditions are not satisfied, the poverty trap is more serious than in our static model. When the economy is specialized in the labour-intensive good, that is, trapped in a vicious circle of underdevelopment, there is no equilibrium path that "breaks out of the vicious circle" to reach the good steady state.

We should again ask how today's rich countries were able to reach the good steady state. It can be shown that the existence of an equilibrium path from the bad to the good steady state depends, among other things, on the international relative price of labour-intensive goods. If this relative price is high, then it is less likely that such an equilibrium path exists. When industrialization was confined to a few countries, the relative price of labour-intensive goods must have been low, since only a few countries were able to produce complex goods at a low cost. It is likely that an equilibrium path from the bad to the good steady state existed back then but not today, given that many economies can now produce the complex good relatively cheaply.

Now, if this is the case, how can we explain the remarkable growth of the Republic of Korea, Taiwan (province of China) and the other miracle countries? We could argue that these economies had a lower inter-temporal discount rate or adopted economic policies that made entrepreneurs more flexible in their investment decisions (see Matsuyama, 1992). Alternatively, we could argue that these countries adopted the right policies at the right time; that is, they opened their economies to international trade when world conditions were such that "miracles" were possible—there was an equilibrium path from the bad to the good steady state.

Evidence

One crucial assumption in all the models presented in this section is that significant advantages arise when input suppliers and users locate close to each other. The models above capture this feature by assuming that all inputs are non-tradable, but, of course, this assumption is made only to simplify the analysis. Similar results would arise under the more general assumption that transportation costs (broadly conceived) for certain inputs are significant. But is it reasonable to expect such transportation costs to be high?

The answer is clearly positive for an important group of inputs, namely producer services (such as banking, auditing, consulting, wholesale services, transportation and machine repair). Indeed, producer services are usually regarded as non-tradable goods in empirical research (Kravis, 1985; Kravis and Lipsey, 1988). This classification is consistent with the finding that some non-local firms that sell services to distant regions charge more for their services (see Daniels, 1985). Perhaps the most powerful evidence for the non-tradable character of producer services comes from indirect sources. Firms rely extensively on local sources for their inputs—and more so with service inputs. Marshall (1988) used data from manufacturing establishments in three city regions of the United Kingdom (Birmingham, Leeds and Manchester) to show that almost 80 per cent of the services purchased by manufacturers were obtained from suppliers within the same planning region.

Additional evidence for the non-tradability of services comes from the broad association between employment change in the manufacturing and service sectors in the European Economic Community (EEC), North America and Japan—which can be explained only by significant transportation costs for such services.[10] Appendix 3 contains a more detailed review of the relevant evidence for producer services and shows that the main assumptions made in the previous model are empirically consistent for producer services: manufacturing is more efficient where producer services are available in better quality and higher diversity (love of variety), and producer services are produced with increasing returns technologies, and they are in general non-tradable, so that the location of producer services affects and is affected by the location of manufacturing.

The costs of using physical intermediate goods not produced locally may also be quite high. Many producer services are involved in taking those intermediate goods from the point of production to where they will be used. If these services are lacking or costly, using imported physical inputs may be costly. Moreover, when inputs have to be imported, there is a higher risk that they will not arrive at the right time or with the correct specifications, forcing firms to hold large inventories of such inputs (see Wilson, 1992, pp. 101–4 for some concrete examples). As Porter (1992) argues, the presence of local suppliers is an important determinant of the comparative advantage of nations, because it provides "efficient, early, rapid, and sometimes preferential access to the most cost-effective inputs" (p. 102).[11]

One might think that falling transportation costs would eventually make our multiple equilibria result irrelevant, since all economies would have virtually the same access to inputs produced anywhere in the world. But transportation costs have also fallen for final goods, which could make multiple equilibria more likely. See Krugman (1991) for a more detailed discussion of this point.

Rosenberg (1982) presents several examples in US economic history in which linkages were crucial to the development of particular industries. He shows how the capital-goods industry developed through a process of specialization and division of labour of the kind specified above—with backward and forward linkages playing a crucial part.

Caballero and Lyons (1992) provide direct evidence on the empirical significance of positive externalities through backward linkages. They show that over relatively long horizons intermediate goods are important in accounting for productivity growth—that is, productivity increases in an industry when output increases in industries that

supply it with inputs. Additional evidence for positive localized externalities through backward linkages is provided by Holmes (1995), who shows that, as implied by theory, manufacturing establishments located near other establishments within the same industry use purchased inputs more intensively than do relatively isolated establishments. Holmes also finds that industries that are geographically dispersed according to the Glaeser-Ellison criteria do not exhibit this pattern—the importance of input purchases for firms in such industries is not affected by their location. This finding suggests that geographic concentration is connected with the division of labour as it enlarges the local industrial scale and permits the production of more varieties of non-tradable inputs.

Finally, Hummels (1995) notes that most of the richest countries are clustered in relatively small regions of Europe, North America and east Asia, while the poorest are splayed around the rest of the world. More concretely, Hummels shows that income per capita decreases with distance from core countries (United States, Germany and Japan). He argues that transportation costs (broadly conceived) for inputs may partly explain this phenomenon, since it is more expensive to buy specialized inputs in countries that are further away from core countries, where a large variety of such inputs is produced.

DYNAMIC KNOWLEDGE EXTERNALITIES

Perhaps the most well known mechanism through which positive externalities arise is local knowledge spillovers. They are usually cited as an explanation for the concentration of high-tech industries in Silicon Valley and along Boston Route 128. In their static formulation such externalities generate results similar to those derived in the previous section. That is, if we assume that one of the two sectors of the economy enjoys aggregate external increasing returns to scale, then the economy could have a convex production possibilities frontier and multiple equilibria. But the more interesting implications of these types of externalities arise when we realize that they are better seen as dynamic externalities. I will now consider several different types of models that formalize such dynamic knowledge spillovers.

Education and research externalities

Stokey (1991) formulated a model in which positive externalities arise from education. In her model there is a continuum of goods. Workers choose to spend some fraction of their finite lives receiving an education, which is required to produce more advanced, more valuable goods. As a by-product of education, there is an increase in "social knowledge", which in turn makes education less costly. This model leads to a steady state rate of growth in which workers spend a fixed fraction of their lives pursuing an education. But since education becomes less costly with time, the absolute level of education completed by workers continues to increase, which allows for the introduction of more advanced goods.[12]

One of the interesting results of this model concerns the impact of trade on growth. For a poor economy opening up to trade lowers the relative price of advanced goods and the rate of return to education. As a result the time that agents spend in education drops. But this effect is only temporary—eventually, the economy continues to grow at the autarky rate. The classic welfare gains from trade are thus (partially or more-than-completely) compensated by negative dynamic effects.

The recent literature on endogenous growth has focused mostly on the knowledge spillovers that arise from research and development (R&D) as opposed to education or learning by doing. The classic contribution here is Romer (1990). In this model growth is based on the invention of new intermediate goods by firms that recover R&D costs from profits made by selling those inputs. R&D requires skilled labour, which is a fixed factor (or, more generally, a non-reproducible factor), so externalities in R&D are essential to maintain growth in the long run. As in most of the subsequent literature, externalities arise in Romer's model as a by-product of private R&D efforts. In other words, firms devoted to the invention of new inputs produce not only a profitable input design but also public knowledge that benefits other firms in the R&D sector.

Grossman and Helpman (1992) have worked out the implications of this type of model for convergence, trade and development. The results depend critically on whether knowledge spillovers are assumed to be national or international. The interesting results for our purpose are those obtained under the assumption that such spillovers are national in scope (later, I discuss whether this assumption is reasonable). Grossman and Helpman show that when research entails the introduction of new non-tradable intermediate goods that are used in all sectors, the rate of innovation increases in a poor country (that is, a country with a low endowment of skilled labour) as a result of trade, because trade leads to specialization in unskilled-labour-intensive goods, releasing skilled labour from the production of skilled-labour-intensive goods that can be used in the research sector. On the other hand, when research entails the invention of new tradable intermediate goods (or non-tradable intermediate goods that are specific to the production of a tradable final good), hysteresis results: the country that starts with more accumulated knowledge (more experience in research) often ends up conducting all of the research and enjoys a higher income level in steady state. Of course, differences in country size and government policies may offset the role of history.

A more relevant scenario for our present purposes, also considered by Grossman and Helpman (1992) (extending a previous model by Krugman, 1979), arises when the North innovates and the South imitates. Grossman and Helpman assume that knowledge spillovers are stronger within a country than across countries, so the North's superior research experience gives it a comparative advantage in innovation. But the South can imitate the goods and technologies developed in the North, which prevents the South from falling behind. The steady-state income gap between the North and the South is determined such that the North's advantage from its superior experience in research is exactly matched by the South's advantage from its ability to imitate the North's innovations relatively inexpensively.[13]

The types of models we have considered in this subsection can explain both the absence of absolute convergence across countries and the fact that there are no countries falling steadily behind the rest (see Parente and Prescott, 1993). Still, these models do not explain why some poor countries are able to take off in a process of rapid growth and catch-up.

External learning by doing

Perhaps the simplest setting in which to think about the importance of dynamic externalities for economic development is a world in which knowledge is gained accidentally in the production process—and such knowledge spills over to the rest of society. In this case there are no dynamic considerations in the allocation of resources at any point in time. Since learning by doing is completely external to the firm, resources simply flow to those sectors in which the *present* return is higher.

As a start, think about an economy with two goods, *y* and *z*, and labour as the only primary factor of production. Suppose there is industry-specific external learning by doing in both industries (knowledge generated in *y* does not benefit industry *z* and vice versa), but learning is slower in industry *z*, say because production of good *z* is simpler. In this scenario, as shown in Lucas (1988), each country specializes completely according to its present comparative advantage. Whether trading countries converge or diverge depends on the elasticity of substitution in consumption between *y* and *z*. The most interesting scenario is the one in which the two goods are substitutes in consumption (that is, they have an elasticity of substitution higher than one). Then, the country that specializes in good *y* enjoys a faster real rate of growth, since the declining relative price of *y* does not outweigh its faster rate of learning by doing. The opposite occurs when goods are not substitutes (that is, the elasticity of substitution is lower than one). When the elasticity of substitution is equal to one, the real growth rates are the same (see Appendix 4 for a formal treatment of this issue).

Now suppose that there are inter-industry knowledge spillovers, but knowledge is generated only in sector *y*. Even with an elasticity of substitution in consumption of one between goods *z* and *y*, the countries that initially specialize in good *y* eventually enjoy a faster real rate of growth. Because they eventually produce both goods, they enjoy faster learning by doing in both the *y* and *z* sectors.

This simple model is suggestive of the effects that trade can have on growth when there is external learning by doing. But we must move beyond this model if we want to draw relevant implications for development policy.

Bounded learning by doing and inter-industry spillovers

The simple model we reviewed above assumed unlimited learning by doing for each good. But this assumption is contrary to the available empirical evidence on learning by doing, which suggests that such learning takes place only in the initial stages of production (see references in Young, 1991). After a certain amount of a good has been produced, little can be learned from producing more. In other words, learning by doing is bounded for each good. But bounded learning by doing is important in the long run only if the knowledge generated in the production of a particular good is useful for the production of other goods, that is, only if there are inter-industry spillovers (or spillovers from one generation of goods to the next). Absent such spillovers, the rate of growth is completely determined by other factors, such as the rate of innovation (Young, 1993).

What is the evidence on the existence of inter-industry spillovers? Jaffe (1986) finds that a firm's R&D productivity is higher the higher is the R&D effort of its technical neighbors (see also Bernstein and Nadiri, 1988). Jaffe, Trajtenberg and Henderson (1993) find evidence of localized knowledge spillovers from patent citations. Strictly speaking, this is evidence for R&D spillovers rather than learning by doing spillovers, but it suggests the existence of inter-industry knowledge spillovers in general. Irwin and Klenow (1994) find no evidence of inter-generational spillovers in the semiconductor industry.

Inter-industry spillovers arise not only directly, as ideas flow across sectors, but also indirectly, through input linkages. Rosenberg (1982) provides several examples of how innovations in particular industries extended strong positive pecuniary externalities to other industries. Breshnahan (1986) gives an econometrically well-documented example of this phenomenon. He shows that the banking, finance and insurance industries derived large gains from the use of high-speed computers that were not captured by manufacturers of computers.[14]

Young (1991) considers a model that incorporates both of these realistic features of learning by doing: bounded learning and inter-industry spillovers. His model involves a continuum of goods that differ only in their potential for learning by doing—goods with a higher potential (more advanced goods) have a lower cost after all learning by doing opportunities have been exhausted. At any given time learning by doing will have been exhausted for some goods but will continue in the remainder, and very advanced goods will not be produced because of their high current cost. As learning by doing continues, it generates positive spillovers for more advanced goods, leading to a lower cost of production. As a result such goods are produced eventually, leading to more learning by doing and more spillovers—and ultimately more advanced goods enter the production stage. The model thus exhibits continuous growth characterized by the production of a changing basket of goods: advanced goods continuously replace relatively simple goods whose learning by doing potential has been exhausted.

The most interesting result of this model is that for a poor country (that is, a country that has had relatively little time to learn and accumulate experience) trading with richer countries always lowers the rate of learning by doing. The intuition is simple: because richer countries have accumulated more experience, they have a comparative advantage in more advanced goods. Trade thus has the poor country specializing in backward goods—which have exhausted their learning by doing potential—and the rich country specializing in advanced goods—which still have potential for learning by doing. Of course, trade is not necessarily welfare-reducing because of the classic static welfare gains from trade. But it is a remarkable result that a country's growth rate always decreases as a result of trade with a richer country.

Two effects could change this result.

- *Income effects.* In Young's model preferences are separable, so the rich country consumes more of all goods relative to the poor country. In fact, consumers from the rich country consume goods that are more backward than the most backward goods consumed by consumers from the poor country. A more natural model that allowed for income effects on the composition of the consumption bundle, such that higher incomes lead consumers to purchase more advanced goods, would lead to different results, because trade between a rich and a poor country would involve trade in intermediate goods (backward for the rich country and advanced for the poor country). The poor country has a comparative advantage in the most backward goods, but the rich country does not buy such goods, so trade is less likely to have the negative impact that it has in Young's model.[15]
- *Factor proportions effects.* Young's model features only Ricardian trade, arising from the different levels of experience of each country. But the economic miracles of east Asia started exporting labour-intensive goods. Now, if there are some goods that are both advanced from the poor country's point of view (with high learning by doing potential) and labour-intensive, then the Hecksher-Ohlin comparative advantage may outweigh the Ricardian comparative disadvantage. The poor country would thus specialize in these goods, and the rate of learning by doing need not fall.

Neither of these two effects can by itself lead to higher learning by doing in the poor country as a consequence of trade with a richer country. But together they can: the poor country would export only advanced, labour-intensive goods, thereby accelerating the rate of learning by doing. This may explain how trade positively affected the economic miracles of east Asia. Indeed, the goods that these countries exported during their first stages of industrialization were labour-intensive and relatively advanced. For instance, their typical exports during this period were toys and shoes designed for consumers in the affluent countries of the west that were much more complex than the toys and shoes produced for the local population.

The effect of trade on a small economy

What are the implications of Young's model for a small economy that takes prices as given? Consider a world equilibrium with trade between the South and the North, and assume that the South is composed of a number of identical small economies, all of which take prices as given. Equilibrium considerations do not determine the goods that these small economies will produce, since they determine only resource allocation for the South as a whole. The allocation of resources for any Southern country is a matter of luck: a particular Southern economy is just as likely to be producing goods with high learning by doing potential as goods that do not generate any knowledge (see Lucas, 1993). Since there is no comparative advantage among the Southern countries, a tariff in any one would eliminate all imports from the South. A general import tariff can thus have drastic effects on learning by doing: it would lead to a drastic increase in learning by doing for any country unlucky enough to be producing backward goods with no learning by doing opportunities, while it would have the opposite effect for any country lucky enough to be specialized in advanced goods.

Of course, the result that the allocation of resources for any individual Southern economy is indeterminate is an artifact of our simple framework. For instance, a more realistic framework would have Southern economies with a higher endowment of skilled labour (that is, higher education levels) specializing in more advanced goods and enjoying faster learning by doing. The effects of a general import tariff are thus likely to depend on individual country characteristics, not only on luck.

International knowledge spillovers

The effects of dynamic knowledge spillovers that we have been discussing depend crucially on the assumption that such spillovers are stronger at the national level than at the international level. That is, we have been assuming that knowledge diffuses faster within the country than across borders. What is the available evidence on this issue?

Let us first go back to our discussion of convergence. We focused there on the role of physical and human capital accumulation in the process of growth and convergence. But this is not the whole story. As Solow (1956) showed, a large part of the growth experience must be explained by forces other than factor accumulation. This is the famous Solow residual, which is usually attributed to exogenous technical progress. But as Romer (1986, 1990) has argued, we must be able to explain the process of innovation (that is, we must make technical progress endogenous) if we are to understand the remarkable growth experience of the past centuries. We must also understand the role of ideas in the propagation of growth across countries. How does the diffusion of knowledge explain convergence—or its absence—across countries?

Although, as mentioned above, Barro and Sala-i-Martin (1995) do not find convergence for their whole set of countries, they do find convergence for certain groups: US states and regions (1880–88), Japanese prefectures (1930–90) and the 20 original OECD countries (1960–85). Plausible explanations for convergence within these groups are labour migration and capital mobility. But Barro and Sala-i-Martin show that, at least for US states and regions, migration and capital mobility do not explain a significant part of the convergence process. Is it possible to explain convergence among these economies as a result of the flow of ideas?

Some recent papers suggest that we can. Coe and Helpman (1993) and Coe, Helpman and Hoffmeister (1995) show that both poor and rich countries benefit substantially from R&D performed in other countries and that such spillovers arise at least partially as a result of trade. They show that countries that are more open to international trade benefit more from international R&D spillovers, and that this effect is stronger when trade is biased towards countries that spend more on R&D. The authors argue that trade acts as a conduit for international R&D spillovers by allowing countries to import technologically advanced inputs that make their economies more efficient.

There are two basic ways in which such spillovers materialize from imports of specialized inputs. First, imports of new varieties of inputs generate higher productivity because users of those inputs are able to keep part of the surplus that arises from their use (that is, they keep the area between their demand curve and the price line). Second, as emphasized by Eaton and Kortum (1995), when firms sell higher quality versions of the same input they may extract all the surplus that arises from the use of that input as opposed to the one currently used. But this surplus is only "marginal"—input users capture all of the surplus that arises from using the current version of the input rather than the version with the lowest quality.

Of course, international knowledge spillovers arise not only through trade—ideas may cross borders just as they flow within countries. Irwin and Klenow (1994) show that this is the case for the semiconductor sector. In particular, they show the existence of substantial spillovers from the knowledge accumulated in production (learning by doing) and that such spillovers are just as strong among firms in different countries as they are among firms within a single country.

At a purely theoretical level the geographical scope of knowledge spillovers depends on our definition of knowledge. Knowledge can be of four types: (inarticulate) knowledge embodied in workers, knowledge that is disseminated through human interaction, knowledge that is disseminated through the written word and knowledge incorporated in new varieties of inputs. The first and second types of knowledge are likely to generate spillovers that are geographically limited, maybe even restricted to a smaller geographical unit than a country (such as Silicon Valley). In contrast, the third and fourth types of knowledge are more likely to cross international borders, although the movement of the fourth depends on the tradability of the inputs that incorporate the new knowledge. Even the first two types of knowledge may diffuse to other regions and countries after a lag, possibly when such knowledge develops to the point when it can be disseminated in written form.

This point, together with the recent empirical results of Irwin and Klenow (1994), Coe and Helpman (1993) and Coe, Helpman and Hoffmeister (1995), leads to the presumption that international knowledge spillovers are significant, and thus the results showing divergence in some models with external learning by doing should be interpreted with care. A recent model developed by Klundert and Smulders (1995) highlights the importance of international spillovers for economic development. They show that if international spillovers are strong enough, then there is convergence, whereas intermediate cases (in which international spillovers are present but not strong enough) may entail a steady state in which both the North and the South grow at the same rate, but there is no convergence: the South does not catch up to the North.

POLICY IMPLICATIONS

What are the policy implications that emerge if we accept the view that the observed lack of convergence is due to externalities and the positive feedback mechanisms they generate? What are the correct development policies in a world characterized by multiple Pareto-rankable equilibria and path dependence?

First, it is important that government not make it more difficult for the economy to reach a good outcome. For instance, government should avoid fiscal policies that generate inflation and high interest rates, since those conditions shrink agents' time horizons and make an expansionary equilibrium path less likely to emerge. For the same reason excessive regulation and high investment taxes should be avoided. Moreover, government should not adopt policies that make the effective size of the economy smaller (such as promote large government bureaucracies), because the economy is less likely to be able to sustain the deep division of labour that leads to high wages and high returns to capital. Of course, this policy advice coincides with the well-known policy prescription of the neoclassical model.

There are other policies important in a world characterized by externalities that are also not controversial. Subsidies to education are recommended because of the knowledge spillovers they generate (Stokey, 1991), because they improve the diffusion of knowledge (Shleifer, 1991) and because sectors that generate more linkages and knowledge spillovers are likely to be relatively intensive in skilled labour (Rodríguez-Clare, 1995). Policies to promote competition may be recommended, because the freedoms to enter an industry and invest are important in the diffusion of knowledge (Shleifer, 1991). But we must be careful here, because such policies also decrease the incentives to generate knowledge in the first place. Policies that promote foreign investment also seem beneficial, since foreign firms are likely to be a conduit for technology transfer and knowledge spillovers (Shleifer, 1991). Foreign investment may also generate positive backward linkages if foreign firms produce sufficiently complex goods (Rodríguez-Clare, 1996c).

Are there more radical policy implications arising from the theories of economic development reviewed in this chapter? It would seem that, when there are multiple Pareto-rankable equilibria, government should coordinate entrepreneurs to reach the good equilibrium. Government wants to convince economic agents that there will be a boom in domestic demand (in the Murphy-Shleifer-Vishny model) or in the variety of intermediate goods (in the model with backward and forward linkages), thus inducing entrepreneurs to generate the boom themselves. But we know very little about how expectations are formed and even less about how expectations react to government policies. As Matsuyama (1994) points out, government policies aimed at coordinating expectations may backfire. This could happen if, for instance, economic agents have the general impression that government intervention is bad for the economy. It also seems unreasonable that government could "force" the economy to allocate resources as in the good equilibrium. More generally, as Matsuyama (1994) argues, the problem of coordinating a whole economy is "of such fundamental difficulty that no algorithm can solve it" (p. 2).

Somewhat less radical and more reasonable policy advice could be given if we knew which sectors generate strong positive externalities. What are the implications of the different models in this regard? In the Murphy-Shleifer-Vishny model, because positive externalities arise from aggregate demand spillovers, the appropriate policy would favour industries that pay high wage premiums or industries that direct demand towards industrial goods. In thinking about these policies, we should note that the distribution of income may be important in generating aggregate demand spillovers. For instance, as pointed out by Shleifer (1991), because large public projects are usually capital- rather than labour-intensive, they are unlikely to generate a strong increase in domestic demand for industrial goods.

In the rest of this section I focus on the policy implications that arise in models with linkages and localized knowledge spillovers. In these models the government will want to support industries generating the strongest linkages and localized knowledge spillovers. But is it possible to identify these industries? There are at least two approaches that we can follow. The direct approach involves determining at least an ordinal measure of externalities for each particular industry, so that we can rank industries in terms of the strength of

the externalities they generate. The second approach is more indirect. It entails determining the characteristics shown by industries that generate strong externalities.

Measuring externalities

The model of backward and forward linkages presented in the fourth section indicates clearly which measure captures the impact of a firm on the economy through the generation of linkages: the quantity of employment generated in upstream industries per unit of labour employed directly. The higher is this ratio, the more positive is the backward linkage effect of the firm. This measure differs from those commonly used in that, because it is derived in a general equilibrium framework, it considers how the expansion of one activity comes at the expense of other activities that could be generating linkages. This model is thus especially relevant for measuring linkages in economies with no surplus labour.

But this measure relies on several restrictive assumptions made to keep the model tractable. To measure the linkage potential of an industry in a real economy, we must generalize at least the most restrictive of these assumptions.[16]

First, the model assumes that all inputs are non-tradable. But in the real world most inputs are tradable, although subject to transportation costs. All else equal, we would prefer an investment that generates demand for inputs with high transportation costs. Second, the model assumes a simplistic technology for the production of specialized inputs. In reality some inputs may rely intensively on resources that are very scarce locally (that is, skilled labour), in which case the economy cannot take advantage of the linkages that might arise from some new economic activities. In other words, supply constraints may break the chain of reactions that build linkages. Third, different types of inputs may have different degrees of love of variety. Assume there are two inputs, x_1 and x_2, both of which are available in a continuum of varieties. Assume also that production exhibits a stronger love of variety for input x_1 than for input x_2. An investment that generates a strong demand for input x_1 thus benefits the economy more than one that generates a strong demand for x_2.

Fourth, some inputs may be produced with constant returns to scale, in which case an increase in their demand would not generate any positive externalities.[17] Finally, the model assumes that all industries use the same inputs. But in reality some inputs are industry-specific. As a consequence the linkages generated by the expansion of one particular industry may not benefit the rest of the economy.

It should be obvious from this discussion that the measure of linkages obtained after making these generalizations is of little practical use given data constraints. Of course, we could try to determine whether particular industries generate externalities, as has been done in many studies (see Stewart and Ghani, 1991 for a survey of this literature). But it is difficult to use this literature as a basis for policy because most studies do not *quantify* externalities and thus do not determine which sectors generate the strongest externalities. Moreover, most of those studies are not linked tightly to theory, making their findings more difficult to interpret.

The direct measurement of the strength of knowledge externalities for each industry seems even more difficult than that of externalities arising from linkages, since we know very little about the process by which those externalities arise.

Instead of trying to measure externalities directly, we could instead use the degree of geographic concentration of an industry as an indirect measure of the strength of the localized externalities in that industry, since localized externalities lead to geographic concentration. Because there are costs to geographic concentration, we expect to find a higher degree of geographic concentration for industries that exhibit stronger localized externalities. There are two problems with this approach. First, industries may be concentrated geographically for several reasons, such as the natural characteristics of some regions (for example, soil and climatic conditions are important in explaining why 78 per cent of wine industry employment is concentrated in California). Following this approach, it is necessary to know which industries are geographically concentrated because of natural conditions and which are concentrated because of localized externalities. This undertaking seems to be feasible. The second problem arises because the degree of geographic concentration is determined by the balance of the industry-specific benefits and costs of geographic concentration. As long as the costs of geographic concentration vary by industry, we cannot measure the benefits purely from the observed degree of geographic concentration.[18] We need more information about industry-specific costs before we can use geographic concentration as an index of localized externalities.

Characterizing industries that generate strong externalities

Designing a successful industrial policy does not require the knowledge of which industries generate the strongest externalities—information about the characteristics of those industries may suffice. For instance, if we were to verify that the industries that generate strong backward linkages are intensive in skilled labour or physical capital (as in Rodríguez-Clare, 1996a; Rodrik, 1994a), then it may be beneficial for an intermediate economy (an economy that has an endowment that makes it potentially competitive in industries that are intensive in skilled labour or physical capital) to set high minimum wages as a way to induce the economy to specialize in those industries (see Rodrik, 1994a).

Can we draw some general inferences about the characteristics of the industries that generate strong externalities? For the model with backward and forward linkages we can argue that industries at earlier stages of the industry cycle are more likely to generate strong backward linkages because such industries are more likely to exhibit strong love of variety (since firms at earlier stages of the industry cycle are not sure which inputs they will need) and to use inputs that are less tradable.[19] For the model with bounded learning by doing and inter-industry spillovers, it also seems likely that the industries that generate stronger spillovers are those at the earlier stages of the industry cycle, since these are the industries that still have learning by doing potential.

Insofar as linkages and knowledge spillovers are localized, we would expect to find young industries highly concentrated geographically, since this would allow firms to benefit from knowledge spillovers. To verify this empirically, I regressed total factor productivity growth (a proxy for the age of an industry) on geographic concentration for industries at the four-digit level, as measured by

Ellison and Glaeser (1994), and found no significant correlation.[20] In fact, the 15 industries that exhibit the highest geographic concentration in the United States are not necessarily the glamorous high-tech industries that one might initially think have the strongest externalities (table 3.1). Of course, this could be due to the fact that, as we mentioned above, geographic concentration arises not only from localized externalities but also from natural advantages that pull some industries to particular regions.

In any case, if we verified that young industries generate stronger localized externalities, what are the implied policy recommendations for developing countries? One may think that the obvious answer is protection or support of advanced industries. But this answer is not so clear because, given their resource endowments, it may not be realistic to expect developing countries to "capture" industries at a very early stage of the industry cycle. That is, the industries that are advanced from the point of view of developing countries (those that they could "capture" through special support) may have already passed through the stage of their cycle in which they generate strong localized externalities.[21] We need more research here before we can make a more definitive policy recommendation.

Table 3.1. The fifteen most geographically concentrated industries

Four-digit code	Industry	Ellison-Glaeser index of geographic concentration
2371	Fur goods	0.63
2084	Wines, brandy, brandy spirits	0.48
2252	Hosiery, n.e.c.	0.44
3533	Oil and gas field machinery	0.43
2251	Women's hosiery	0.40
2273	Carpets and rugs	0.38
2429	Special product sawmills, n.e.c.	0.37
3961	Costume jewelry	0.32
2895	Carbon black	0.30
3915	Jewelers' materials, lapidary	0.30
2874	Phosphatic fertilizers	0.29
2061	Raw cane sugar	0.29
2281	Yarn mills, except wool	0.28
2034	Dehydrated fruits, vegetables, soups	0.28
3761	Guided missiles, space vehicles	0.25

Source: Ellison and Glaeser (1994).

Supporting the entire manufacturing sector

As a final point, I should mention that an alternative to a policy of supporting the industries that are believed to generate the strongest externalities is a policy of subsidizing the entire manufacturing sector—a policy that has long been advocated by cautious economists (Balassa, 1981; Little, Scitovsky and Scott, 1970). This policy advice is based on the belief that the manufacturing sector generates strong externalities. Is there any evidence of supporting this belief? Recent papers by Caballero and Lyons (1992), Chan, Chen and Cheung (1995) and Khan and Bilginsoy (1994) point to a positive answer. We must be careful with these results, however. Other sectors (such as agriculture or services) may also display positive externalities, in which case the correct policy prescription would depend on which sector has the strongest externalities.

Still, it is interesting to ask what the correct policy would be if the manufacturing sector has the strongest positive externalities. Recent models of externalities and positive feedback mechanisms may help us in this regard. For instance, in the context of the model of backward and forward linkages presented in the fourth section, if we view the sector producing complex goods as the manufacturing sector, then the appropriate policy may entail subsidizing the production of the complex good or subsidizing entry (as opposed to production) in the intermediate-goods sector. It seems important that future research study the best ways to support the manufacturing sector in terms of information requirements and public costs.

APPENDIX 1. THE MURPHY-SHLEIFER-VISHNY MODEL: A FORMAL TREATMENT

Consider a one-period economy with a continuum of goods indexed by $q \in [0,1]$ and a representative consumer with a utility function:

$$\int_0^1 x(q)dq.$$

Labour, available in quantity L, is supplied inelastically and serves as the numeraire. Cottage production converts one unit of labour into one unit of output. The modern technology involves a fixed requirement of F units of labour and then $1/\alpha$ units of labour for each unit of output, with $\alpha > 1$. If an entrepreneur invests in the modern technology, he becomes a monopolist. Given the unitary price elasticity of demand for each good, it is optimal to charge a price of 1, which is the price charged by the competitive fringe that produces with the cottage technology. Since consumers spend equal shares of their income on each good, when income is y, a monopolist makes profits π given by:

$$\pi = [(\alpha - 1)/\alpha]y - F \equiv ay - F,$$

where a is the markup. When a fraction n of the goods are produced with the modern technology, aggregate profits are $\prod(n) = n(ay - F)$. And since $y = L + \prod$, $y(n)$ is given by:

$$y(n) = \frac{L - nF}{1 - na}.$$

Letting $\pi(n) = ay(n) - F$ denote individual profits as a function of n, we can see that $\pi(0) < 0$ implies $ay(0) = aL <$ F. But $\pi'(n) = ay'(n)$, which is negative (positive) if $aL - F$ is negative (positive). This implies that if no industrialization is an equilibrium ($aL < F$), then it is the only equilibrium. There will be an industrialization equilibrium only if $\pi(1) > 0$, but this happens only if $aL >$ F, which rules out the no-industrialization equilibrium.

Now, let v represent the wage premium and assume that $\alpha - 1 > v$. Firms with the modern technology must pay workers $1 + v$. Then,

$$\pi = [(\alpha - 1 - v)/\alpha]y - (1 + v)F = by - (1 + v)F,$$

where $b \equiv \dfrac{\alpha - 1 - v}{\alpha}$.

Moreover, we have $y(n) = [L + vnF + \prod(n)]/(1 - vn/\alpha)$. $\pi(0) < 0$ implies $bL < (1 + v)F$. But $\pi'(0)$ is equal in sign to $y'(0) = \prod'(0) + vF + L(v/\alpha) = bL - F + vF + (v/\alpha)L$. Therefore, we can have $\pi(0) < 0$ and $\pi'(0) > 0$, which happens when $bL - (1 + v)F < 0$ but $bL - (1 - v)F + (v/\alpha)L > 0$.

APPENDIX 2. A SIMPLE MODEL OF MULTIPLE EQUILIBRIA WITH BACKWARD AND FORWARD LINKAGES

Consider an economy in which the only primary factor is labour, available in total quantity L. There are two final goods, z and y, and one intermediate good, x, which comes in a continuum of varieties. Variety is indexed by the real number j. Goods z and y can be traded freely in the world market, and both countries are "small" in the sense that they do not affect the international prices of z and y, denoted respectively by P_z and P_y (in terms of some international numeraire).

The intermediate good x is non-tradable. The measure of varieties of x actually produced will be denoted by the real number $n \geq 0$ (for $j \leq n$, variety j of x is available). $p(j)$ will denote the price of variety j of intermediate good x. Each variety of the intermediate good x is produced with a simple decreasing average cost technology: there is a fixed requirement of one unit of L and each additional unit of $x(j)$ requires one additional unit of L.

Both final goods are produced with a Cobb-Douglas production function using labour and a composite intermediate good, X, which is assembled from a continuum of differentiated intermediate goods:

$$Q_s = \delta(s) L_s^{\beta(s)} X_s^{1-\beta(s)} \qquad (1a)$$

$$X_s = \left(\int_0^n x(j)_s^{\alpha}\, dj\right)^{1/\alpha} \qquad (1b)$$

for $s = z, y$, where $\delta(z)$, $\delta(y)$, $\beta(z)$, $\beta(y)$ and α are constant parameters, and we assume that $\beta(z), \beta(y), \alpha \in (0,1)$.[22] We also assume that $\beta(z) > \beta(y)$, which implies that the y-industry uses intermediate goods more intensively than the z-industry.

The specification of the production function in equations 1a and 1b implies that there are returns from the division of labour in the production of intermediate goods. To see this, note that because of the symmetric way in which different varieties of x enter in equation 1b and because of concavity ($0 < \alpha < 1$), efficiency requires firms producing final goods to use the same quantity of all available varieties. That is, efficiency requires that $x(j) = x$ for all $j \leq n$. Letting L_x denote the amount of labour devoted to the production of intermediate goods (excluding the labour used to produce the fixed requirement per variety), then:

$$L_x = \int_0^n x(j)dj = nx.$$

The production function for s can then be written as:

$$Q_s = \delta(s) n^{\phi(s)} L_s^{\beta(s)} L_x^{1-\beta(s)}, \qquad (2)$$

where $\phi(s) \equiv (1 - \beta(s))(1 - \alpha)/\alpha$ and $s = z, y$. Equation 2 shows that an increase in the available variety of intermediate goods increases total factor productivity in the production of final goods. This property is commonly referred to as *love of variety* for inputs. Since $\beta(z) > \beta(y)$, then $\phi(y) > \phi(z)$, which implies that producers of y have stronger love of variety than producers of z. This will play an important role in this model.

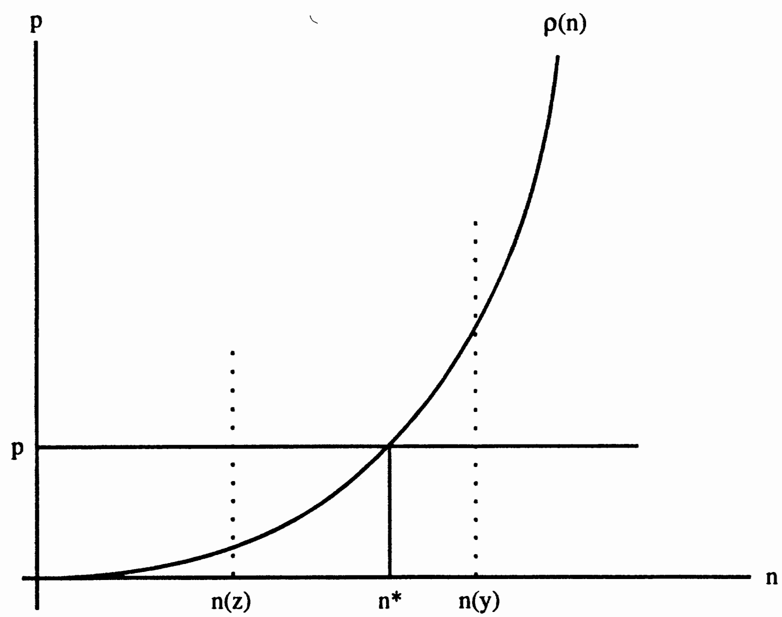
Each firm producing a variety of x is better off choosing a variety that is not already being produced by another firm. Therefore, variety j of x, if it is produced, is produced by a single firm, which then chooses the price $p(j)$ to maximize profits. In other words, there is monopolistic competition in the intermediate goods sector.

Given n, we have a constant marginal rate of transformation between z and y—the production possibilities frontier is linear. Formally, letting c_s represent the unit cost for good s, then for some constant A, $c_z/c_y = \rho(n) = An^{\phi(y) - \phi(z)}$. Therefore, except for the knife-edge case in which $p \equiv P_z/P_y = \rho(n)$, there will be complete specialization in the production of final goods: there is complete specialization in the production of y if $\rho(n) > p$, there is complete specialization in the production of z if $\rho(n) > p$, and any combination is an n-equilibrium if $\rho(n) = p$.

Since $\phi(y) - \phi(z) = [\beta(z) - \beta(y)] / \theta > 0$, then $\rho(n)$ is increasing (figure A1). Therefore, as n increases, the production possibilities frontier rotates so that the marginal cost of z in terms of y increases. As we can see in figure A1, there is a level of n, n^*, such that if $n > n^*$, there is complete specialization in y and vice versa. The intuition is simple: since y uses intermediate goods more intensively than does z, it benefits comparatively more from an increase in the variety of intermediate goods. Thus as n increases, the unit cost of y falls relative to the unit cost of z.

To characterize the equilibria we now need to consider the zero-profit condition in the intermediate-goods sector. Since the y sector uses intermediate goods more intensively than the z sector, the demand for intermediate goods is higher when there is complete specialization in y than when there is complete specialization in z. Therefore, when the economy specializes completely in y, the equilibrium variety of inputs is higher than when the economy specializes completely in z. Letting $n(s)$ denote the variety of

Figure A1: Input variety and the pattern of production



inputs for which the zero-profit condition in the intermediate-goods sector is satisfied when there is complete specialization in s, then $n(y) > n(z)$ (see figure A1).

If n^* lies in the interval $[n(z), n(y)]$, there are multiple equilibria. If $n = n(z)$, then $n < n^*$, so there is complete specialization in final good z, and given the definition of $n(z)$, the zero-profit condition holds. Similarly, if $n = n(y)$, then $n > n^*$. There is complete specialization in final good y and the zero-profit condition holds.

If n^* lies outside the interval $[n(z), n(y)]$, there is a single equilibrium. If $n^* < n(z)$, the unique equilibrium involves $n = n(y)$ and complete specialization in y. There is no equilibrium with $n = n(z)$, because since $n(z) > n^*$, the $n(z)$-equilibrium involves complete specialization in y and hence the zero-profit condition would not be satisfied. Similarly, if $n^* > n(y)$, the unique equilibrium involves $n = n(z)$ and complete specialization in z.

When there are multiple equilibria, the z equilibrium is characterized by a small variety of intermediate goods, low wages and specialization in the simple good z, while the y equilibrium is characterized by a large variety of intermediate goods, high wages and specialization in the complex good y. In the z equilibrium there is a coordination failure: everyone would be better off in the y-equilibrium, but no individual wants to produce y given

the small variety of intermediate goods available. But it is not profitable for anyone to produce a new variety of the intermediate good because, since the economy is completely specialized in the production of z, there is a low demand for intermediate goods.

There are two types of distortions that could potentially justify government intervention in this context. First, for each equilibrium, as shown by Dixit and Stiglitz (1977), there is a suboptimal level of entry—that is, n_s is lower than the optimal level of n when the economy is completely specialized in $s = z, y$. Second, there is a coordination problem. The government would like to coordinate economic agents so that the y equilibrium is chosen. One way of doing this is by imposing a tariff on y so that the z equilibrium disappears.

APPENDIX 3. PRODUCER SERVICES, AGGLOMERATION ECONOMIES AND ECONOMIC DEVELOPMENT

Here, I will briefly survey the literature on producer services to explain in more detail what producer services are, their importance in industrial and developing economies, their relation to the manufacturing sector and the locational pattern they follow. The main emphasis is to show that the basic assumptions used in the model with backward and forward linkages have empirical validity for producer services: manufacturing is more efficient if producer services are available in better quality and greater diversity (love of variety), and producer services are produced with increasing returns technologies and they are in general non-tradable, so that the location of producer services affects and is affected by the location of manufacturing.

The idea that non-tradable intermediate goods produced with increasing returns are important for efficiency in the production of final goods has been used often in the urban and regional economics literature to account for the formation of cities and industrial complexes, and to explain differences in economic performance across regions. The main example of non-tradable intermediate goods cited in this literature is producer services, which include services like auditing; administrative and computer consulting; financial, wholesale and transport services; and equipment maintenance.

Producer services began to receive particular attention with the publication of the seminal work by Greenfield (1966), which pointed out the growing importance of producer services as a source of new jobs and as an essential "lubricant" for the manufacturing sector and the economy in general. Since then, the non-tradable character of producer services has been increasingly recognized, and an important literature is now developing on the spatial characteristic of producer services (Stanback 1979; Daniels 1985; Marshall 1988).

Definition of producer services. Marshall (1988) defines producer services as those "services which supply business and government organizations, rather than private individuals, whether in agriculture, mining, manufacturing, or service industries. Based on these criteria, producer services are concerned with financial, legal, and general management, innovation, development, design, administration, personnel, production, technology, maintenance, transport, communication, wholesale distribution, advertising, and selling" (p. 13).[23]

These services can be produced within the organization, or they can be acquired from outside specialized sources. Greenfield (1966) enumerates several reasons why firms may prefer to contract out services rather than produce them "in house". They can be reduced to the following basic argument: the adequate provision of a service necessitates specialized and up-to-date personnel "that many small and medium-size firms cannot afford to employ on a full-time basis" (p. 42). But even larger firms may prefer to contract out the provision of certain services to keep staff at a manageable size, to decrease "influence" and "agency" costs (Milgrom and Roberts 1988; McAfee and McMillan 1990) and to maintain "a small, compact, relatively homogeneous labour force" (Greenfield 1966, p. 43). Demand for outside intermediate services thus arises from a combination of economies of scale due to indivisibilities in the production of such services and "organizational diseconomies of scale" (to paraphrase McAfee and McMillan). In the rest of this section I focus exclusively on the producer services provided to firms by external agents, for these are the producer services that generate the kind of phenomena we are interested in.

The importance of producer services in industrial countries. There is by now wide recognition that the proportion of workers not engaged directly in the production process in firms has been increasing (Gershuny and Miles, 1983). Here, however, we are concerned only with the provision of producer services by specialized external sources, and we will thus concentrate only on the importance of the producer service sector as an independent industry, measured both by its share of the labour force and GNP. This task is difficult because different authors use different classifications of industries. The problem is that some services are sold to firms and some to consumers, so that only part of the industry can be said to be producing producer services. Moreover, problems with data availability compound the problem significantly. Since the purpose here is only to give an approximate idea of the importance of producer services in the economy, we will give the estimates of authors using different classifications without going over the details of the definitions used.

In a study of the industrial structure of employment in EEC countries, Gershuny and Miles (1983) show that producer services account for a proportion of total employment, that ranges from 9.8 per cent in Italy to 14.6 per cent in Belgium. Greenfield (1966) estimates that in 1960 13.2 per cent of the labour force was employed in producer services, and 22.7 per cent of national income originated in that sector. Singlemann (1970) notes that, already in 1970, producer services had surpassed the personal services sector in the United States with respect to the proportion of employment in the service sector. In terms of the importance of producer services as an intermediate-goods industry, Stanback (1979) shows that "more than a fourth of all intermediate outputs are services" (p. 17). We can see from table A1 that rich countries allocate a substantial part of their labour force to this class of producer services.

The importance of producer services for efficiency in manufacturing. The direct evidence of the importance of the availability of a wide range of producer services for the efficiency of manufacturing is still largely anecdotal and relies mostly on qualitative studies. Marshall (1988) cites some studies, which establish that accurate and up-to-date services to management, marketing services, the services of engineering consultants in the organization of goods production, and research, development and technical support services to the innovation process contribute positively to firm performance.

In a study of the service sector in developing countries, McKee (1988) argues that producer services are very important for the efficiency of the leading industrial operations in those countries. Furthermore, he argues that producer services "aid in establishing effective linkages between various stages of the manufacturing process" (p. 20).

Producer services and increasing returns to scale. So far, I have cited studies that support the idea that the availability of a wide variety of locally provided producer services is an important determinant of the efficiency of other industries in the area. This by itself implies only that the location of producer services is influenced by the locational pattern of other industries. However, there is also evidence that many specialized producer services are produced with increasing returns, which implies that producer services play a more active role in the explanation of the uneven development of regions and in the explanation of multiple equilibria.

Table A1. Proportion of employment in selected services for some industrial countries

Canada	10.52	Japan	7.41
Denmark	8.42	Sweden	7.61
France	8.48	Switzerland	9.41
West Germany	6.78	United Kingdom	10.44
Italy	3.78	United States	11.09

Note: The data on employment in selected services are taken from the OECD Summary Statistics, 1990. The services included are financing, insurance, real estate and business services. The year for the data varies with the country, but ranges from 1984 to 1987.

Faini (1984) mentions various studies that support the assumption that increasing returns to scale prevail in the production of producer services (banking, accounting, transportation, electricity, and so on). Moreover, professional services (like consulting, auditing and engineering) are information intensive; and this in itself suggests the presence of decreasing average costs because of the non-rival property of information as an input of production (Romer, 1990). "Overall, available empirical evidence, while not conclusive, provides encouraging support for the assumption that increasing returns to scale prevail in the production of non-traded inputs" (p. 310).

Agglomeration economies and economic development. Together, love of variety, non-tradability and increasing returns lead to the existence of agglomeration economies and the concentration of producer services and manufacturing activities in cities and regions. The possibility of cumulative and uneven regional development arises.

Marshall (1988) surveys some studies that support the argument that remoteness from places in which certain producer services are produced will reduce the efficiency and competitiveness of an industry. He notes that "work examining the relationship between accessibility and economic development in Europe has identified an association between peripherality and relatively low incomes per head" (p. 58).

In her work on the origin, growth and decline of cities and their importance for economic development, Jacobs (1969, 1984) also argues that the abundance of producer services is a consequence and a fundamental cause of the high productivity of economic activity in cities. Stanback (1979) holds similar views: "The modern capitalistic economy has been made possible by the development of a number of strategic business services or service-like activities—transportation, distribution, communication, and financial—many of which individual producing firms could not have performed themselves. The rise of producer service firms has sparked the proliferation and growth of goods-producing firms as well as the other way around" (pp. 21–2).

There is also evidence to support the view that more-developed economies allocate a greater proportion of primary resources to the production of producer services. Singlemann (1970) shows that the higher is the level of per capita income, the larger is the proportion of the labour force in producer and social services.

Moreover, there is evidence indicating that the intensity with which intermediate services are used increases with development and technical change. For instance, Gershuny and Miles (1983) have shown that the intensity with which producer services are used in the primary and manufacturing industries in the United Kingdom increased between 1963 and 1973. Marshall (1988) suggests that a plausible explanation for this trend is that "the pace and complexity of economic and technical change have necessitated greater utilization of more specialized and sophisticated services by the production sector" (p. 42).

APPENDIX 4. A SIMPLE MODEL OF EXTERNAL LEARNING BY DOING WITH TWO GOODS

I now present a simple model that illustrates how trade may have dramatic effects on growth rates when there is external learning by doing. Consider an economy with two goods, y and z, and in which labour is the only primary factor of production. At time t, production of good s ($s = z$ or y) takes place according to:

$$Q_s = A_s(t)\mu_s L,$$

where μ_s denotes the fraction of the total labour force L engaged in production of good s. We assume that $A_z(t)$ and $A_y(t)$ evolve according to:

$$\mathring{A}_s(t) = A_s(t)\delta_s(\beta_{sz}\mu_z + \beta_{sy}\mu_y),$$

where δ_s, β_{sz} and β_{sy} are positive parameters for $s = z$, y, and we assume that $\delta_y > \delta_z$. That is, sector y benefits more from the accumulation of knowledge than does sector z.

Preferences are given by the following CES utility function:

$$U(Q_z, Q_y) = (\alpha_z Q_z^{-\rho} + \alpha_y Q_y^{-\rho})^{-1/\rho},$$

where α_z, $\alpha_z \geq 0$, $\alpha_z + \alpha_y = 1$, $\rho > -1$ and $\sigma \equiv 1/(1+\rho)$ is the elasticity of substitution between z and y.

In autarky a country would simply allocate resources to these two goods depending on the relative cost and preferences at each point in time. The allocation of resources at time t, that is, $\mu_z(t)$ and $\mu_y(t)$, would then determine $\mathring{A}_z(t)$ and $\mathring{A}_y(t)$, the rate of change in prices, and the dynamics of $\mu_z(t)$ and $\mu_y(t)$.

Trade can have dramatic effects on such dynamics. When two countries start trading, specialization is determined according to static comparative advantage. The effect of trade on growth for a particular country then depends both on how trade affects its rate of knowledge accumulation through its impact on the country's allocation of resources and on the rate of change of world relative prices. To see this more clearly, let us consider two simple cases:

(*i*) $\beta_{zy} = \beta_{yz} = 0$, $\beta_{zz} = \beta_{yy} = 1$ (no inter-industry externalities).

In this case, as Lucas (1988) shows, the initial pattern of specialization is preserved and reinforced through time. The country that has an initial comparative advantage in good y, say country A, specializes in that good, so the relative cost of y in that country falls with time. The opposite happens in the other country, say country B.

Since country A specializes in good y, it enjoys a faster rate of knowledge accumulation. But this is somewhat offset by a decreasing relative price of y. With a unitary elasticity of substitution between z and y ($\sigma = 1$), for example, prices exactly offset the faster rate of knowledge accumulation in country A, so the rate of growth of income in both countries is the same. But if $\sigma > 1$, then the declining price of y only partially offsets the faster rate of knowledge accumulation in country A, so country A has a faster rate of income growth than country B. The opposite occurs when $\sigma < 1$.

Now, if $\sigma > 1$ and $a(t) \equiv A_y(t) / A_z(t)$ is not too low at $t = 0$, then $a(t)$ will be increasing for a country in autarky. Therefore, when countries A and B start trading, the country that "started" earlier (the richer country) will have a comparative advantage in good y, so trade will lead to divergence.

(ii) $\beta_{zz} = \beta_{zy} = 0, \beta_{zy} = \beta_{yy} = 1, \sigma = 1.$

In this case only production of good y generates new knowledge, but this knowledge also contributes to higher productivity in sector z. When trade is opened up between countries A and B, country A will have a comparative advantage in good y. Hence, trade allows country A to enjoy a faster rate of knowledge accumulation than the poor country (country B), where knowledge accumulation will stop completely (because of complete specialization in good z). But given $\sigma = 1$, the declining price of y completely offsets this advantage, and the real rate of growth of both countries is equalized. However, the world relative price of y is falling faster than country A's relative cost of y, so at some point country A starts to produce both goods. At this point, it is clear that country A's real rate of growth becomes higher than country B's. Concretely, at time t, country A's real rate of growth will be faster than country B's by $\delta_z \mu_y(t)$, where $\mu_y(t)$ is the share of the labour force devoted to the production of good y in country A. It can be shown that $\mu_y(t)$ converges to some $\mu_y^* > 0$, thus countries A and B diverge.

NOTES

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1. It is assumed here that steady states entail no growth, as in the pure Solow model with no technical change. With exogenous labour-augmenting technological change the steady state implies a constant income per efficiency unit of labour, not income per capita. The main implications remain the same.
2. This calculation assumes a tax rate on capital of 30 per cent in the United States and also that the after-tax rate of return on capital is equalized across countries. This exercise is very similar to one performed by Lucas (1990), who finds that if the difference in income per capita between India and the United States is to be explained by differences in capital-labour ratios, the marginal product of capital in India would be about 58 times the marginal product of capital in the United States.
3. See Parente and Prescott (1994) for a very interesting paper that argues that the stylized facts of economic development can be explained with a model of technology adoption in which poor countries benefit from their technological backwardness but remain poor because of high barriers to technology adoption.
4. A possible problem with this approach is that it takes economic policy as exogenous, whereas in reality economic policy may be influenced by future growth prospects. If this is the case, it makes the results in Sachs and Warner more difficult to interpret.
5. Wage premia are not crucial; similar results arise when firms operating modern technologies have to pay above-market returns to factors other than labour.
6. Fafchamps and Helms (1996) develop this story formally.
7. Hirschman (1958) made similar assumptions in his analysis of linkages. He argued that domestically produced inputs were more conducive to the development of further economic activity (pp. 99–100), and he believed that there was a "minimum economic size" for the profitable operation of most activities (p. 101). Finally, he implicitly assumed that a set of inputs was indispensable for the production of each good—an extreme form of love of variety.
8. Notice that this argument is based entirely on the scale of the industry. Greif and Rodríguez-Clare (1995) show that there may also be a role for the composition of the industry (the number of firms) in generating agglomeration economies. That is, other things equal, productivity is higher in a region where the industry is composed of many small firms than in a region where the industry has the same scale but is composed of a few large firms. The reason is that when the industry is composed of many small firms, industry-specific intermediate-good suppliers will be less concerned that final-good producers will act opportunistically and pay low prices. More industry-specific inputs will thus be produced, making production more efficient.
9. Closing the economy to international trade is not necessarily optimal when the economy is at the bad equilibrium, however (see Rodríguez-Clare, 1996a).

10. "Those countries such as Portugal, Canada, Japan, and the USA in which manufacturing has grown or remained stable during the last decade have among the strongest service sector growth records, and in all of these apart from Japan, service employment has grown by more than 30 per cent. In contrast in Belgium and the United Kingdom, where manufacturing employment declined by approximately 30 per cent between 1974 and 1984, employment growth of only 15.7 per cent and 12 per cent respectively was recorded in service industries. Employment change in producer services such as transport, storage, communications, and finance and office-based business services are most strongly related to manufacturing performance" (Marshall 1988, p. 40).
11. In regional economics the conventional wisdom seems to be that when the value-weight ratio is low, when the time of need of inputs is uncertain, when low quantities are needed and when quality and time of delivery are essential, then it is very convenient to have the supplier of the input close by (Vernon, 1966; Scott and Storper, 1987).
12. Azariadis and Drazen (1990) also consider a model in which there are externalities in education. They show that in some cases such externalities may lead to path dependence: when the economy starts up with a low level of education, education is costly and no one chooses to become educated. Thus the level of education drops, and the economy eventually reaches a steady state with a low level of education. In contrast, if the economy starts with an education level above a certain threshold, then education is not too costly. People choose to become educated, taking the economy towards a steady state with a high level of education.
13. Rodríguez-Clare (1996b) develops an alternative model to consider what determines the rate of technology adoption in a small open economy. It is shown there that trade barriers have a negative effect on the rate of technology adoption, thereby increasing the income gap between North and South.
14. Glaeser and others (1992) use data on the growth of industries in cities to show the existence of inter-industry externalities. But it is not clear whether such externalities arise through the flow of ideas or as a result of backward and forward linkages.
15. See Lucas (1993) for an interesting argument concerning how this type of income effect may lead poor countries to benefit from trade even when there is bounded external learning by doing.
16. The following discussion is based on Rodríguez-Clare (1996c).
17. Hirshman (1958) was careful on this point. He noticed that certain linkages do not significantly affect the rest of the economy, as in the case of what he called "satellite industries", which require only a small economic size to be profitable (p. 102).
18. To think about industry-specific costs of geographic concentration, suppose that entrepreneurs living all around the country get an idea or an opportunity to enter an industry *X*. Suppose these entrepreneurs like to locate where they already live because of reallocation costs, because they already know that environment and possibly because of particular advantages of that region. These costs explain why not all entrepreneurs move to the place where the industry is concentrated.
19. The non-tradability of inputs for young industries arises because at earlier stages of the industry cycle firms depend on short delivery times for inputs and often specify the design of the inputs to their suppliers, making it important to have constant contact with them. The possibilities of doing so are enhanced by proximity between firms and suppliers.

20. The correlation coefficient is 0.027 with a t-statistic of 0.5.
21. There are other well-known problems with protecting infant industries in developing countries, such as the possible decrease in competition and efficiency. Moreover, as shown in Rodríguez-Clare (1995), such a policy may lower the rate of technology adoption.
22. The production function of the composite intermediate good *X* uses the functional form first proposed by Dixit and Stiglitz (1977) as a specification for a utility function, and later applied to production theory by Ethier (1982).
23. In a classic paper on the service sector Katouzian (1970) provided a different classification of services. The category that comes closest to the group of producer services are what he calls "complementary services". He says that "these services have been complementary to the growth of manufacturing production in two ways: as complementary factors to urbanization, and as necessary links to the process of round-about or capitalistic production" (pp. 366–7).

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