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Receptive Capacity of Established Industries as a Limiting Factor in the Economy's Rate of Innovation[1]

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Patterns of intersectoral growth have featured prominently in the economic development literature for several decades. In particular, a fierce controversy between proponents of "balanced" and "unbalanced" growth dominated much of the discussion on development tactics in the 1950s and 1960s. Although the debate eventually died down and development economics has largely switched its focus to other areas, the question of the role of buoyant industries in promoting economic growth has persisted in other guises. For example, in recent decades there has been considerable, if fluctuating, interest in the ability of a few rapidly growing, and generally technologically advanced, industries to improve *aggregate* economic performance, as well as dispute as to whether this requires government involvement through the use of "industrial policy" or can best be achieved through purely private, market-based initiatives.

In this paper, we use but also challenge some of the building blocks of growth theory provided by Dahmén, Rostow, and Schumpeter as we investigate the relationship between rapidly growing sectors, or those with the potential for rapid growth, and sectors that are already established and "mature".[2] Drawing in part on earlier concepts but placing them in an evolutionary context, we show that long-run structural change in developed economies may depend heavily on maintaining the short- and medium-run competitiveness of established industries because these often provide the major sources of demand required to offset the R&D costs associated with innovation. To fill this role effectively, firms in established industries need adequate levels of "Receptive Capacity", i.e. access to the intellectual, physical, and financial resources that will allow them to adopt innovations quickly. Secondly, building on some of the insights of the New Growth Theory, we argue that firms may actually improve their returns on R&D by judiciously allocating spillovers to other firms. Finally, we conclude that, far from being a separate part of an R&D process that follows onward from innovation, diffusion is often an important driver of

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2 Somewhat roughly, by an "established" industry, we mean one in which technological change is incremental and the rate of growth is low. As a result of contact with innovations, however, established industries may nevertheless be "rejuvenated" to a degree through important transformations in their product and process technologies and increases in their rates of growth (Langlois and Robertson 1995: 76–77).

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development and innovation. As a result, policies that encourage innovation but neglect diffusion to established industries may be self-defeating because the Receptive Capacity of established industries must be nurtured to encourage investment in R&D in the future.

In the next three sections of the paper, we briefly consider the conceptual role of the introduction of innovating sectors into advanced economies, and present a typology to analyze the forward linkages between innovative and established industries. This is followed by a discussion of the significance of spillovers from new industries to established ones in encouraging innovation. Finally we explore the role of diffusion as a driver in innovation.

SECTORAL GROWTH AND ECONOMIC DEVELOPMENT

Throughout the 1950s, development economists and economic historians debated the role of individual sectors in promoting economic growth. An important strand of the discussion revolved around questions of the generation and allocation of investible funds—on whether it was better to concentrate investment in a few areas that seemed especially promising for promoting growth and modernization, or whether investment should be allocated more evenly and include existing traditional sectors as well as new ones. As Nurkse (1953) pointed out, the economies of developing countries were often caught in "vicious circles" in regard to both supply and demand. The establishment of a single large shoe factory (as Rosenstein-Rodan 1943 used in a famous example) would clearly not, in itself, generate enough demand to purchase the total output of the plant: the workers and owners would spend much of their income on other items. As it is necessary to provide reasonable certainty that there will be enough demand for the additional output to justify investment in new capacity, Nurkse advocated a program of "balanced growth". If investment were to take place simultaneously in a wide and "balanced" range of sectors,[3] the total number of workers would demand enough of the whole selection of goods to absorb the output of all of the plants taken together even though the workers at no single plant would create enough demand for its specific product.

In his book, Nurkse (1953) tried to construct a coordinated approach to a number of issues of interest to development economists following the Second World War. These include shortfalls in demand and investment and the perceived need to introduce a modern sector to achieve improvements in productivity. If these were not addressed together, the result might be not economic development but rather the creation of a "dual economy" in which modern and traditional sectors coexisted without the former offering enough stimulus to drive development in the latter. As first used by Lewis (1954) and his followers, dualism referred to imbalances between labor markets in advanced and traditional sectors,[4] but it was later extended to include

3 Nurkse (1953: 11) uses the analogy of a "balanced diet" to show why consumers need to have access to a wide selection of items to absorb additional income resulting from increased productivity.

4 Although Lewis and others generally considered dual labor markets to be a feature of developing economies, Kindleberger (1967) profitably used the concept to examine why the economies of Western Europe were able to grow rapidly after the Second World War with relatively low levels of inflation.

"financial dualism", "sociological dualism", "organizational dualism", and (of most interest to us in what follows) "technological dualism" (Myint 1985).

By the end of the 1950s, balanced growth had come under attack as a practical remedy for dualism. Rostow (1960a, b) and Hirschman (1958) were especially provocative in contending that development could be achieved most effectively through investment concentrated in a few especially promising sectors. Hirschman (1958: Chap. 6) developed the concept of "linkages" to demonstrate how the creation of some industries could lead to aggregate effects that substantially exceed the weights of the industries themselves. When backward linkages (to suppliers) or forward linkages (to customers) are strong, the creation of a modern industry can lead to the expansion of other sectors by generating demand or creating pecuniary externalities (Scitovsky 1954) for intermediate producers or final customers. These effects can be magnified considerably where there are potential economies of scale that could not be exploited in the past and price elasticities of demand are large. After surveying the linkages of a number of industries, Hirschman concluded that iron and steel was probably the most important sector on which to build development in the conditions of the late 1950s.

At about the same time, Rostow argued that "leading sectors" were needed to generate the "take-off into sustained growth".[5] As defined by Rostow (1960b: 52), leading sectors are "Primary growth sectors, where possibilities for innovation or for the exploitation of newly profitable or hitherto unexplored resources yield a high growth rate and set in motion expansionary forces elsewhere in the economy." These are supported by "Supplementary growth sectors, where rapid advance occurs in direct response to—or as a requirement of—advance in the primary growth sector." Rostow (1963: 6) also emphasized the importance of "forward effects" in which a leading sector

> created the setting in which new industrial activity was induced, either by cutting the cost of an input to another industry; by providing a new product or service whose existence was a challenge to the enterprising to exploit; or by creating a bottleneck whose removal was evidently profitable and which therefore attracted inventive talent and entrepreneurship.

Essentially, in common with Hirschman, Rostow emphasized the importance of encouraging the growth of sectors with widespread linkages to other parts of the economy.[6]

In effect, although Rostow and Hirschman challenged the proposition that growth in all sectors would be equally important to the macroeconomy, they affirmed that development does require a degree of balance—that industries must move forward in groups if they are to have a generalized impact on economic development. In this

5 According to Higgins (1968: 186), who is scathing about Rostow's stages theory, "One thing however, is clear; no matter how critical Rostow's colleagues may be of his system, his terminology is here to stay. The expressions, 'the take-off' and 'self-sustained growth,' are thoroughly entrenched in the literature, and will continue to be used by development economists, including the present writer." It is ironic that, 30 years on, these expressions seem, in fact, to be dated, while the more mundane term "leading sector" is still attractive because of its simplicity and accuracy in describing the concept that Rostow had in mind.

6 Kuznets (1966: 142–143) makes a similar point in his analysis of the importance of the metal products sector to the development of other sectors.

respect, therefore, their theories are similar in thrust to the earlier concepts of Erik Dahmén (1970 [1950], 1989), and to subsequent elaborations by Bo Carlsson and Gunnar Eliasson (2003). In a pioneering work on Swedish economic development, Dahmén (1950 [1970]) put forth the idea of growth occurring through *development bloc[k]s*. He defines a development bloc (1989: 109) as:

> a set of factors in industrial development which are closely interconnected and interdependent. Some of them are reflected in price and cost signals in markets which are noted by firms and may give rise to new techniques and new products. Some of them come about by firms creating new markets for their products via entrepreneurial activities in other industries. This, too, may include the creation of new techniques and new products. In both cases, incomplete development blocks generate both difficulties and opportunities for firms. This analytical approach can contribute to closing the gap between micro and macro analysis.

Carlsson and Eliasson (2003: 440) have built on the ideas of Dahmén to dig more deeply into the dynamics of change than is generally done by neoclassical economists. They propose that economies comprise "technological systems" which are composed of three dimensions:

> (1) a *cognitive dimension* defining the clustering of technologies resulting in a new set of technological possibilities, (2) an *organizational and institutional dimension* capturing the interactions in the network of actors engaged in the creation of these technologies, and (3) an *economic dimension* consisting of the set of actors who convert technological possibilities into business opportunities.

Our interest here centers on the economic dimension. As Dahmén (1989) and Carlsson and Eliasson (2003) have emphasized, the progress of development blocs is by no means certain. Ignorance among both users and producers is often the rule, and knowledge (where it does exist) does not spread quickly or automatically. Furthermore, customers may not find it convenient to adopt an innovation immediately, and financial and other resources may be hard to find. Therefore, Carlsson and Eliasson contend the "competence blocs", through which knowledge of innovation spreads, involve not only innovators (the originators of new ideas) and entrepreneurs (who supply "vertical" linkages) but also customers, who supply the "horizontal" connections across industries that give a development bloc sufficient mass to both reward its instigators and influence the macroeconomy. The creation of linkages in Hirschman's (1958) sense requires the presence of suitable external conditions and can also be eased through conscious agency on the part of entrepreneurs and customers.

The Role of Development Blocs in Mature Economies

The constellation of factors considered by the development economists of the 1950s and 1960s is naturally different than the factors that influence innovation in mature developed economies. Aggregate demand and the aggregate availability of investible funds are not generally crucial bottlenecks in most OECD member countries, nor is it necessary to establish appropriate institutions to overcome the organizational dualism identified by Myint (1985). Nevertheless, as Schumpeter (1950) and others have reminded us, capitalism is not a static framework but one that is in need of continual renewal if it is to function efficiently. In a manner somewhat reminiscent of Schumpeter (1934, 1939),[7] Rostow (1960a, b) called attention to this in his discussion of economic change when he noted that the rate of growth of most industries eventually diminishes. As a result, new leading sectors and development blocs are needed if secular stagnation is to be avoided. He contended, for example, that the slack in growth in national product that resulted from a deceleration in the growth of the cotton industry in Britain after 1840 was taken up by an increase in the demand for pig iron as a result of early railway construction. Subsequently, the chemical, electrical, and light-engineering industries all contributed higher than average growth rates that buoyed the economy despite the maturation of earlier leading sectors. A similar pattern emerged in the USA from the 1840s onwards (Rostow 1960a: 262).

Although much of the pre-1970 literature on development economics has since been relegated to obscurity,[8] the notion that growth is led by particular blocs or sectors remains strong. As the blocs that propelled growth in the third quarter of the 20th century have matured, attention since the 1970s has turned to a search for new industries that could provide further impetus.

Our interest here is not in leading sectors as such, but in their role in conjunction with other sectors in the economy—with the entire development blocs that center on particular industries. Economic change is not intended to generate a new form of dualism, with innovative sectors developing largely independently of established but stagnating industries. To bring widespread benefits, innovation should diffuse throughout the economy through linkages of the sort outlined by Dahmén, Hirschman, and Rostow. As a result, we contend that the proper focus for economic transformation is not on innovative sectors narrowly defined (the approach also taken by Schumpeter), but that transformation is path dependent and innovation needs to be considered in the context of the wider range of sectors that *use* as well as generate innovations.

It is important to think of economic change as proceeding in blocs if for no other reason than that policy discussions often reflect a narrower, and less useful, approach. In the minds of both policy makers and the general public, growth is often related exclusively to innovation in the "high-tech" sectors of the economy. For example, according to a recent OECD working paper (Hatzichronoglou 1997: 4), "... technology is a key factor in enhancing growth and competitiveness in business". Furthermore, he argues that:

> Firms which are technology-intensive innovate more, win new markets, use available resources more productively and generally offer higher remuneration to the people that they employ. High technology industries are those expanding most strongly in international trade and their dynamism helps to improve performance in other sectors (spillover).

Since the mid-1980s, the OECD has developed a number of classification schemes to reflect the extent of technology intensity in various sectors of the economies of

7 As Schumpeter (1934) contended in his discussion of the circular flow, in the absence of innovation the natural tendency of capitalist economies was to equilibrium and the steady state.

8 Krugman (1993) has claimed that early development thought effectively disappeared, largely for methodological reasons. Stiglitz (1993), however, contends that the ideas of Hirschman and others remained important except on the banks of the Charles River (i.e. at MIT).

member countries. The most recent version (OECD 1999) sorts industries according to Overall Technological Intensity (OTI), which is the sum of their direct and indirect R&D intensities. As defined by the OECD, technological intensity looks at industries according to *their* usage of R&D rather than by inquiring whether they develop innovations that are diffused to *other* industries.

As we have argued in another article (Carroll *et al.* 2000), indicators of levels of technology are difficult to interpret. In part, this is because it is not always possible to distinguish between high-, medium-, or low-technology industries in a way that is operationally meaningful. In practice, many industries employ a wide mix of product and process technologies. Houses, in which the brick and mortar are laid out in very traditional ways, may also include wiring for the most modern of electronic gadgets. Automobiles, whose general technology was laid down at the turn of the last century, now contain important computerized components and are built with state-of-the-art robots. Even impeccably high-tech industries may employ very old-fashioned techniques in important parts of their operations. For example, a personal computer ordered over the Internet may consist of a collection of electronic components developed in the past 6 months but then assembled by hand using practices that would not have been entirely out of place in an 18th-century cottage industry.

By obscuring these variations, an emphasis on high-technology and high levels of R&D intensity seriously distorts the actual growth process in mature economies. Even in developed countries, the proportion of the manufacturing output derived from the high-technology industries is relatively modest and their share of the economy as a whole is even smaller. This leads to two conclusions on the relative importance of highly innovative sectors in the overall economic picture.

1. *Most economic growth* in absolute terms *is likely to come from established and generally mature industries.* In the USA, which has perhaps the largest "high-tech" concentration of major economies, the "new economy" sectors of machinery, electrical equipment, telephone and telegraph, and software supplied only about 9 percent of GDP in 1998 (Nordhaus 2001). The remaining 91 percent—the "non-new economy" sectors—accounted for the great bulk of employment, assets, investment, and output. Moreover, Nordhaus (2001) contends that productivity growth in non-new economy sectors has accelerated substantially since 1995 (although not as rapidly as in the new economy sectors). Thus, while the *rate of increase* in output in the highly innovative industries far outstripped the rate of growth in the other nine-tenths of the manufacturing sector, the *total absolute* growth of the less innovative[9] industries was substantially greater. It is highly probable, of course, that in the long run the weighting of the more highly innovative sectors will increase, but the remainder of the economy also needs to be nurtured in the short to medium run because the less innovative sectors are the major employers and repositories of wealth. Moreover, many of them, such as food processing, will not be replaced by new technologies even though they may be transformed in various ways.
2. *The established sectors are a major customer for highly innovative goods.* As Dahmén and Carlsson and Eliasson have shown, although many industries are not

9 That is, what are often termed low- and medium-technology industries.

classified as being highly innovative themselves, they employ the output of highly innovative industries in their products and processes. While silicon chips may be incorporated in office equipment that is also classified as highly innovative, in the end most office equipment is used by less innovative industries or in households. Similarly, consumer durables such as refrigerators and washing machines now employ important electronic components, and many production processes for items as mundane as soups rely on electronic controls and other highly innovative inputs. In the absence of these uses, i.e. if there were no important forward linkages from the highly innovative sector, the market for highly innovative goods would be much smaller. Thus, the demand for the output of highly innovative industries is often derived from the demand for less innovative products. This is particularly important because, as we discuss below, fixed costs are frequently substantial in highly innovative industries and economies of scale are important for their initial growth and subsequent survival.

In short, the creation of development and competence blocs, and thus the viability of highly innovative sectors, depend heavily on the health of the established and mature industries that comprise the rest of the economy, *and on the ability of their existing technologies to incrementally incorporate new highly innovative components*. Competence blocs must draw on a wide range of resources spread throughout the economy, and not just on a core innovation, if they are to provide an impetus for development and growth (Carlsson and Eliasson 2003).

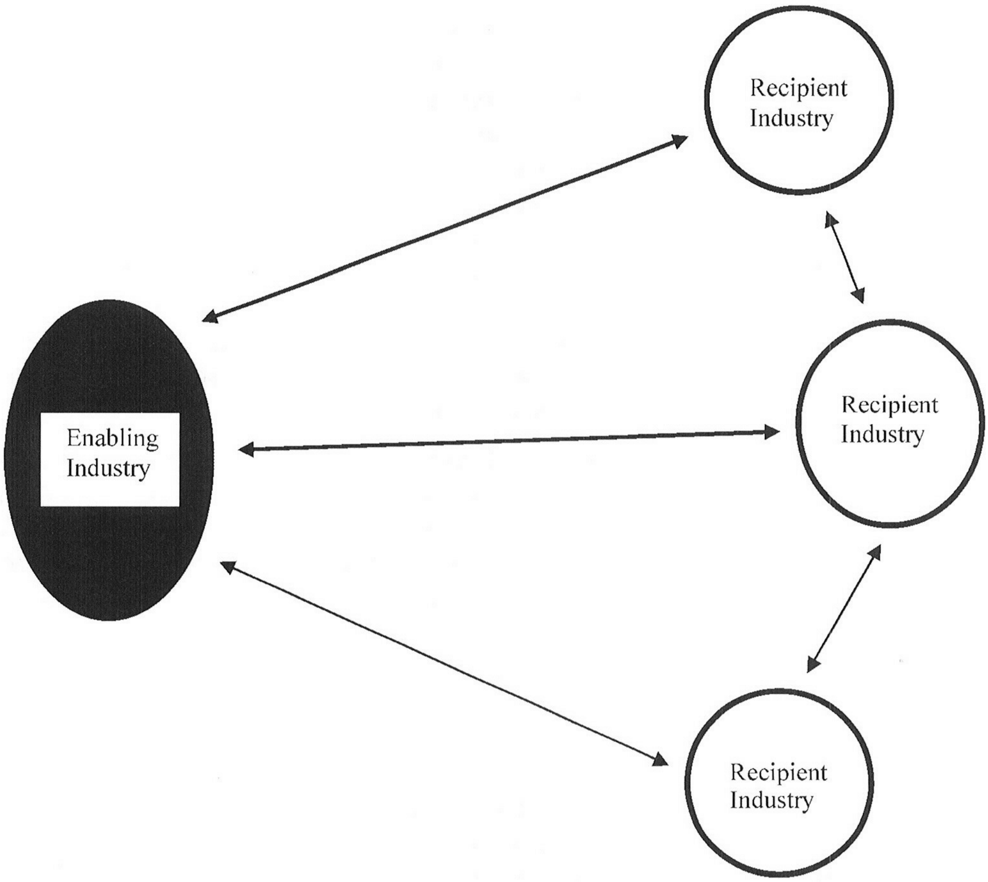
THE ENABLING/RECIPIENT TYPOLOGY

To capture the importance of movements of technology across sectors, we have developed an "Enabling/Recipient Typology".[10] Two definitions are in order: (a) an economic sector is termed an "Enabling sector" if the principal outcome of the innovative endeavors of the firms operating in that sector is to create novel efficiency-enhancing products for use as producer goods in the same sector or other sectors; and (b) a sector buying novel efficiency-enhancing products is termed a "Recipient sector". It follows that, in correspondence with each Enabling sector there will be one or more Recipient sectors.

As noted above, the demand for novel products from the Recipient sectors is essentially a *derived* demand, that is, demand for products not for their own sake but in order to use them in the production of other goods and services. However, the ability of Recipient firms to capitalize on possible advantages emanating from Enabling sectors may be constrained. One restricting factor may be inadequate absorptive capacity on the part of Recipient firms (Cohen and Levinthal 1989, 1990). In order to appreciate and take advantage of Enabling innovations, potential Recipient firms must have access to suitable knowledge embodied in human resources to locate and understand possibly useful innovations. As technological sophistication increases, more investment in the absorptive capacity of the workforce is required to keep pace (Keller 1996). Recipient firms may face other barriers to innovation including a shortage of funds and a lack of complementary assets such as appropriate capital

10 This typology and the accompanying issues of data usage are explained in more detail in Pol *et al.* (2002).

FIGURE 1: CROSS-CAUSATION BETWEEN ENABLING AND RECIPIENT INDUSTRIES



equipment or marketing skills that would allow them to take full advantage of an Enabling innovation. Taken together, these factors constitute the "Receptive Capacity" of firms that affects the extent to which development and capabilities blocs will be completed and the speed at which advances will be made.

Obviously, causation does not run in only one direction, from the Enabling to the Recipient sectors. There are also feedback effects that we discuss in more detail below. These ideas are shown in Figure 1.

The ranking of Enabling sectors is based on the number of their associated Recipient sectors. As a first approximation to this problem, two polar classes can be isolated:

- *High-powered* Enabling sectors (those that influence the most and largest Recipient sectors, such as office and computing machinery); and
- *Non-enabling* sectors (such as wood products and furniture, whose novel products do not have a perceptible influence on the efficiency of other sectors).

In addition, we propose two classes—*moderate* Enabling sectors and *weak* Enabling sectors—whose degree of impact on other sectors through the generation of novel products is noticeable but not profound.

TABLE 1: THE ENABLING/RECIPIENT TYPOLOGY

Economic sectors	Enabling	Recipient
Class 1		
• Office and computing machinery	⊗ ⊗	Ⓡ
• Radio, TV, and commun. equip.	⊗ ⊗	Ⓡ
• Professional goods	⊗ ⊗	Ⓡ
• Electrical machinery	⊗ ⊗	Ⓡ
• Non-electrical machinery	⊗ ⊗	Ⓡ
Class 2		
• Aircraft	⊗	Ⓡ
• Motor vehicles	⊗	Ⓡ
• Shipbuilding and repairing	⊗	Ⓡ
• Chemicals	⊗	Ⓡ
• Pharmaceutical products	⊗	Ⓡ
• Other transportation equipment	⊗	Ⓡ
Class 3		
• Non-ferrous metals	*θ*	Ⓡ
• Non-metallic mineral products	*θ*	Ⓡ
• Metal products	*θ*	Ⓡ
• Iron and steel	*θ*	Ⓡ
• Petroleum products	*θ*	Ⓡ
• Other manufacturing	*θ*	Ⓡ
Class 4		
• Rubber and plastic products	*θ θ*	Ⓡ
• Paper and paper products	*θ θ*	Ⓡ
• Food, beverages, and tobacco	*θ θ*	Ⓡ
• Textiles, apparel, and leather	*θ θ*	Ⓡ
• Wood products and furniture	*θ θ*	Ⓡ

⊗ ⊗ = high-powered enabling sector; ⊗ = moderately enabling sector; Ⓡ = recipient sector; *θ* = weakly enabling sector; *θ θ* = non-enabling sector.

The Enabling/Recipient (ER) typology is presented in Table 1. Even though each class of sectors contains some variety, the categories offer a useful alternative scoping view on a rough-and-ready basis, taking into account the inherent uncertainty involved in dealing with evolving situations.

Since it is difficult in practice to draw a precise line as to where the two intermediate classes begin and end without specific empirical research, the suggested composition of the *moderate* and *weak* Enabling sectors can only be tentative at this stage. Nevertheless, the typology has the attraction of being practical.

As Table 1 shows, there is no one-to-one correspondence between the High-tech/Low-tech classification of industries and the ER typology of sectors. It is true that there are sectors such as radio, TV, and communication equipment that are both Enabling and highly innovative, and similarly, we can find sectors such as wood products and furniture that are both Recipients and have low rates of innovation. But it is also true that the correspondence collapses for most of the remaining sectors.

ESTABLISHED INDUSTRIES AND THE DEMAND FOR INNOVATION

So far, we have concentrated primarily on the effects of innovative industries on the products and processes of established industries. Every forward linkage from an innovative industry to an established one, however, is also a backward linkage from an established industry to an innovative one. It is therefore valuable to know whether—and if so, how—innovative Enabling industries might benefit from their association with Recipient industries that have lower average levels of technological sophistication.

One of the important factors has already been mentioned: both directly and indirectly, established industries are often the primary sources of demand for innovative products (both goods and services). It is true that microchips may be sold to the manufacturers of other advanced electronic products who embed them in their own output. And sometimes, as in the case of microcomputers, there are new products whose existence depends on one or more innovative industries, but in many other cases, such as television sets or toasters, existing products with substantial current markets have been improved by using new components. Even the demand for new products may depend entirely on existing products: VCRs and DVDs would be of little use in the absence of television sets.

The relationship between innovative and established (or Enabling and Recipient) industries is thus more complicated than we have described above. Forward linkages from Enabling industries, as portrayed in Figure 1, are unquestionably important. The incorporation of innovative components in an existing product can spark increased demand by improving the product from the standpoint of final consumers, say through miniaturization. In addition, the Enabling industry may improve production processes and it may transmit pecuniary externalities (Scitovsky 1954) to the Recipient industries. Where there are unexploited economies of scale in the Recipient industries and the elasticities of demand are favorable, both consumers and producers in the Recipient industries can benefit from forward linkages.

But Receptive Capacity is also vital because of the importance of backward linkages from Recipient industries. And, as Figure 1 shows, there are also linkages between different Recipient industries that can reinforce the strength of the backward linkages. Probably the most important impact of backward linkages *to* innovative industries is the effect that they have in covering the substantial fixed costs that are frequently associated with the innovation process. These include the costs of gearing up for production, which are often affected by lumpiness and consequent non-convexities, as well as the costs associated with research and development. Indeed, fixed costs are likely to be a more important consideration for innovative products than for others because R&D expenses may be more lumpy than are the costs of plant and equipment and, as a result, more subject to economies of scale.[11] Easy access to customers is thus of great significance in many innovative industries because it allows for the quick amortization of R&D costs. Furthermore, if there are several Recipient industries, each will contribute to generating economies of scale in the innovative Enabling industry. This will lead to more rapid access to pecuniary externalities on the part of the Recipient industries, creating further economies of scale in the Enabling industry, and so on, resulting in what Nurkse (1953) calls a "beneficent" circle.

In this sort of scenario, a judicious distribution of spillovers may encourage

11 See Langlois (1999, 2001) for a discussion of knowledge reuse in generating economies of scale.

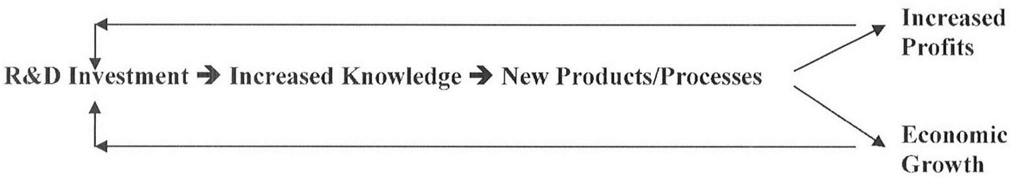
FIGURE 2: LINEAR NEW GROWTH THEORY SEQUENCE.

R&D Investment ➔ Increased Knowledge ➔ New Products/Processes ➔ Economic Growth

investment. In line with Romer and other proponents of the New Growth Theory[12] (NGT), we reject the linear model of R&D (Figure 2) which Kline (1985a, b) has shown is inadequate. In reality, there are various sorts of feedback from later to earlier stages of the development "chain" as new knowledge is acquired and incorporated. We argue that the driver of investments in R&D is the present value of the expected rate of return from a new product or process:

$$I_{R\&D} = F/[PV(EB)].$$

FIGURE 3: FEEDBACKS TO INVESTMENT IN R&D FROM HIGH RATES OF RETURN AND ECONOMIC GROWTH.



The expected rate of profits (EB) is in turn based on (a) the rate of profits from past innovative products and processes, and (b) the state of the economy as reflected in the level of economic growth. Both of these depend on the level of $I_{R\&D}$ in the past. As a result, there is significant feedback in the system (Figure 3).[13]

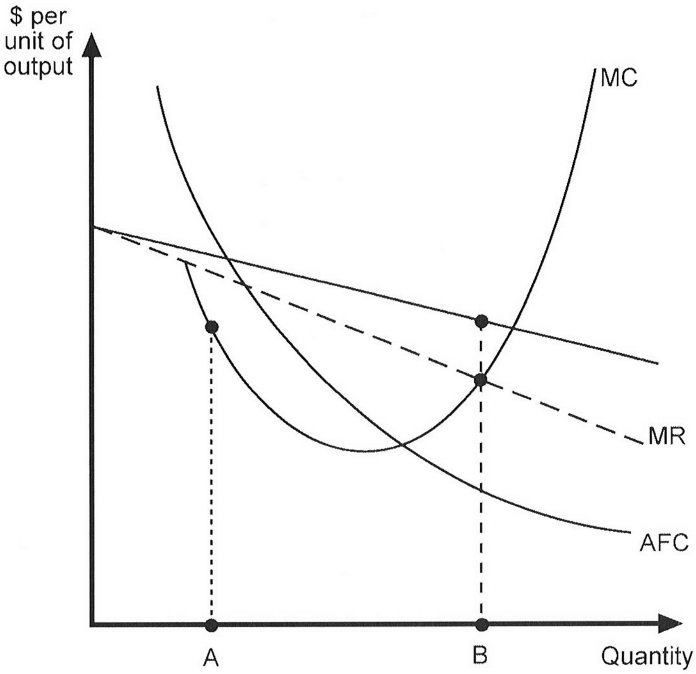
Because $I_{R\&D(n)}$ depends on $I_{R\&D(n-1)}$, future knowledge generation and welfare may be increased by broadening the scope of diffusion of any given innovation and by accelerating the rate at which diffusion occurs since these steps will increase both the present value of the direct returns from $I_{R\&D(n-1)}$ ("increased profits" in Figure 3) and the rate of economic growth.

It follows from our earlier discussion that spillovers in the form of pecuniary externalities to Recipient industries may actually confer an advantage on firms in Enabling industries. When there are high fixed costs resulting from development expenses and hence substantial non-convexities, it may be most profitable for innovating firms to keep prices low (that is, to allow spillovers in the form of

12 There are many types of New, or Endogenous, Growth Theories. Paul Romer (1986, 1990, 1993a, b, 1994) is responsible for at least five. As a family, however, the theories present a broadly similar treatment of research and development and technological change. See also Grossman and Helpman (1991).

13 We accept the argument put forth by Keynes (1973 [1936]: 148–149) concerning the formation of long-term expectations. The only sort of *knowledge* that can possibly be available concerns the past. This does not mean, of course, that investors will assume a linear trend, or otherwise treat this knowledge in an unsophisticated way. Furthermore, decisions are sometimes made by visionaries who are convinced that the past cannot be a reliable guide in an environment that they see as likely to undergo changes in its fundamental underlying variables. What we are arguing, therefore, is not that past performance is the *only* guide that *all* investors use when making decisions, but that it is an important component in innovation decisions in general and that it generates important feedback effects.

FIGURE 4: DIFFUSION OF INNOVATIONS



increased consumer surplus) if the price elasticity of demand exceeds unity. When Moore's Law or some variant pertains and obsolescence occurs very rapidly, as in the case of many electronic items involving high development costs, then generating high volume sales quickly can be especially necessary in order to justify investment in R&D. Under these circumstances, the prior existence of established industries that can serve as customers for firms in innovative industries may be a key factor in encouraging a rapid rate of innovation, but only if Receptive Capacity is high enough to allow development and competence blocs to be completed quickly.

Figure 4 provides a general indication of the potential importance of the diffusion of an innovation as a stimulus to investment in R&D and innovation. In the initial stages of the commercialization of an innovative product, the quantity demanded may be low, say at Point A, perhaps because of ignorance[14] on the part of potential consumers who are either unaware or unconvinced of the value to themselves of adopting the innovation (or who are quite possibly unaware of the very existence of the innovation). Alternatively, Receptive Capacity may be low because of a shortage of other resources such as funding or complementary assets needed to make a purchase of the innovative product attractive. In a situation such as this, the firm offering the innovation is in an unattractive position because its marginal cost curve (MC) lies below its marginal revenue curve (MR). Moreover, average fixed costs (AFC),

14 *Ignorance*, as used here, refers to a situation "in which knowledge or information is already available somewhere or is potentially discoverable but some or all of the potential users have not yet acquired that knowledge" (Robertson 1998: 263). By contrast, there is (inherent) uncertainty when the knowledge or information is not available and not discoverable because it rests on future events that cannot yet be known.

which may be composed largely of capitalized costs of R&D and startup costs, are also high, providing only slow amortization for investment in the current product and acting as a deterrent to future investments in R&D to generate new innovations.[15]

Under such circumstances, it is desirable for the innovative firm to increase the quantity sold quickly, to Point B, where the MC curve intersects the MR curve from below. At this profit maximizing output level, the firm can achieve lower AFC, quickly amortize R&D expenditures, and improve the expected payoff to future R&D activities. This can be accomplished far more easily if demand can be generated among buyers in established industries than if it is necessary to create a group of new complementary industries to provide demand.

But how is an acceleration in the rate of diffusion to be accomplished? If the assumptions of perfect competition—which are clearly inapplicable highly in innovative situations—are relaxed, Austrian and evolutionary economics, in particular, provide some useful clues.

Firstly, why may absorptive capacity be low, resulting in significant amounts of ignorance? The principal cause is the high cost that is frequently involved in both disseminating and acquiring useful knowledge and information. "Solution holders" often find it difficult to establish connections with "problem holders" who could benefit from their knowledge (Robertson 1998). This problem is accentuated when radically innovative solutions arise to problems in established industries with mature technologies whose innovative activities are limited for the most part to incremental changes introduced through familiar channels. When innovations with broad areas of application are developed, firms often do not know where to look for mutually beneficial exchanges of information. This is as vital for firms that want to distribute technological knowledge as for those that can gain by acquiring it. Random scanning of their environments is not an efficient mechanism because firms are not trying to broadcast information per se, but rather the "news", which Stinchcombe (1990) defines as knowledge and information of particular relevance to a firm's needs. Therefore, it is necessary for firms to find ways both of locating the "news" and of quickly and cheaply separating it from other, less relevant, information that they receive.

Other barriers to Receptive Capacity include an unwillingness on the part of existing firms to adjust and adapt to innovation (Dahmén 1989). It may be entirely rational for firms to cling to their existing techniques in the face of a competence-destroying innovation and to run down ("harvest") their existing plant and equipment rather than to modernize (Robertson and Langlois 1994). Furthermore, when markets are depressed, even if for brief periods, firms may be unwilling to invest in innovative techniques if they fear that they will create overcapacity. Replacement of old techniques may have to await the next upturn in economic activity. Finally, the borrowing capacity of firms may be reduced in downswings, again inhibiting their ability to adopt innovations.

Consumers as well as producers may need substantial absorptive capacity if innovations are to be successful. In the subjectivist view of knowledge offered by the

15 As future investment in R&D is based on *discounted expected* rates of return, it is more likely to be stimulated by high and quick rates of return in the recent past than by low and slow rates.

Austrian school of economics (O'Driscoll and Rizzo 1985), there can be no overt demand for a good until potential customers become aware of its existence. Therefore, it is necessary for firms to work *actively* to inform potential consumers of the existence of an innovative good and to seek to persuade them of the value of the good to themselves. In Austrian terms, this may take several forms. Kirzner (1973, 1979) argues, for example, that "entrepreneurial alertness" is required to reduce ignorance by informing potential buyers of opportunities. Advertising may also help would-be customers to assess the value of innovative goods to themselves by describing the innovations in ways that relate to their existing stocks of knowledge.[16] In this way, perceptions can be altered to enhance the probability that consumers will adopt innovations (Rogers 1995). In the absence of efforts to inform and persuade, the overt demand for an innovative product may be stuck at some inadequate level such as Quantity A on Figure 4 if its producers do not disseminate knowledge in a persuasive way that spreads the "news" more quickly, allowing a shift to a more efficient level of demand, say Quantity B.

Entrepreneurial alertness and mechanisms such as advertising, however, are not necessarily efficient in generating demand because they are also subject to limited scope. In the presence of bounded rationality, entrepreneurs cannot be counted upon to move quickly to identify and support all important (or even the most important) sources of demand for innovative products, and advertising and other forms of persuasion are subject to similar limitations. Moreover, as the problem of making contact is multifaceted, potential consumers must also be educated to look in the right places for information.

This is clearly a real problem that requires careful attention. Systemic innovations spread slowly and, while the rate of dissemination of the "news" may have picked up in recent years, it may still be slower than desirable if optimal levels of investment in R&D are to be achieved. As David (1991) has shown, the spread of electrification in developed countries required many decades, beginning in the late 1870s and culminating only after the Second World War. Railways and other important innovations also took many years to reach all areas where they were of potential value. More significantly, despite important improvements in communications, the spread of technologies associated with semiconductors has also taken over half a century since the development of the transistor, and is still in progress. Under these circumstances, it is doubtful if R&D and startup costs are, even now, being amortized at anything like an optimal rate to encourage investment in innovative activities. What seems to be needed, therefore, are improved mechanisms for diffusion, for increasing Receptive Capacity, including more effective government policies to speed up the spread of innovations.

But what sorts of mechanisms and policies would be effective? The argument that we are presenting suggests that procedures designed specifically to increase investments in R&D and in innovative products, desirable though these may be, need to be complemented by other policies that will increase the rate of diffusion. Indeed,

16 In their discussion of consumption, for example, Langlois and Cosgel (1998) contend that consumers evaluate new items on the basis of their current stocks of knowledge and base their consumption decisions on their previous personal experiences. In general, firms could be expected to act similarly, even if with a great deal more formal negotiation to reconcile divergent histories.

policies that accelerate the rate at which innovations are adopted may well reduce the need for policies to increase expenditures on R&D. If the expected rate of return on investments in R&D is increased, discounted for time, then normal market mechanisms should be more effective in inducing satisfactory levels of expenditure on innovative activities.

CONCLUSION—DIFFUSION AS A DRIVER OF INNOVATION

We argue that innovation is a complex process and that policies to encourage economic growth need to reflect this. In particular, the health of more mature, or Recipient, sectors of the economy deserves as much attention as do the interests of the newer Enabling sectors that are often the loci of major innovations. In the absence of backward linkages from the Recipient sectors that comprise the vast bulk of modern economies to the innovative Enabling sectors, there would be little incentive for investment in R&D.

Our analysis suggests at least two important ways in which unreflective policies may be ineffective. Firstly, policies that emphasize innovation by Enabling sectors but neglect diffusion can constrain the benefits that flow from investments in R&D. The more slowly the use of a particular innovation diffuses to its full range of potential customers in Recipient sectors, the less attractive the innovation is in net present value terms. Secondly, the established (Recipient) sectors of the economy are not a burden that retards innovation, modernization, and growth. Established sectors are, in reality, the heart of the economy at any moment, and they provide the short- to medium-run demand for many innovative products. In contrast to Schumpeter and Rostow, but consistent with the arguments of Dahmén and Carlsson and Eliasson, we contend that, from the standpoint of economic growth, the development paths of innovative sectors in mature economies cannot meaningfully be discussed independently of the development paths of established (Recipient) sectors. Thus, from a policy perspective, it may cause serious harm if emphasis is placed on encouraging innovative sectors at the expense of established ones. Except perhaps in the case of defense products, the ability of innovative firms to survive and prosper depends on the extent to which they are able to fit into the context of established industries that dominate mature economies.[17] The fates of Enabling and Recipient industries are frequently mutually reinforcing. While Enabling sectors provide pecuniary externalities and an ability to develop improved and more attractive products for Recipient industries, the recipients provide the markets that innovative firms need to take advantage of economies of scale and amortize their R&D expenses. "Creative updating and replacement" is often a necessary complement to creative destruction.

The policy implications of our argument are too complicated to be fully outlined here. We should note, however, that the rate of knowledge generation, and hence the rate of innovation in an economy, depend heavily on the expected level of profits

17 Export markets may also be targeted if domestic markets are too small. Under current circumstances, however, most innovations with substantial linkages originate in diverse and mature economies such as those of the USA, Japan, and Western Europe. Only subsequently have up-and-coming countries including Korea and Taiwan become significant producers of the innovative products (several product generations on)—and they, too, are significantly dependent for their markets on derived demand for established products in mature economies.

from the R&D activity required.[18] This, in turn, is a function of the expected size of the market for the fruits of new knowledge, or as Nurkse (1953: 6) paraphrasing Adam Smith, has put it, "The inducement to invest is limited by the size of the market." It is well known that the diffusion of new technologies can be prolonged,[19] particularly in the case of systemic innovations such as electrification, the spread of the private automobile, and more recently, the use of computers for business and personal purposes. One important way of inducing the generation of knowledge and innovation, therefore, is to speed up the rate of diffusion. This is especially true when the rate of technological change is seen to be high and the time periods needed for amortization of R&D expenses are correspondingly short. As a result, serious thought should be given to finding ways of increasing the Receptive Capacity of firms in established industries—to boosting their access to the intellectual, physical, and financial resources needed to adopt innovations quickly.

Finally, our analysis augments the NGT by arguing that diffusion should not follow from innovation, but should be seen as an integral part of the R&D planning process. Although it is undeniable that many important discoveries will continue to be fortuitous, the search for markets should begin as early as possible if one accepts that the expected rate of profits from innovation determines levels of investment in R&D and other knowledge-generating activities.

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18 This argument is developed in more detail in Langlois and Robertson (1996). Austrian and evolutionary approaches to the fact that suppliers can induce demand are discussed in Yu and Robertson (1999). As Heertje (1988) has noted, Schumpeter also rejected the standard neoclassical principle of the independence of supply and demand.

19 For a classic exposition, see David (1991).

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