Apresentação

Paulo Bastos Tigre
Professor titular do Instituto de Economia da UFRJ

Ideias fundadoras são aquelas que efetivamente abrem novos caminhos para o pensamento científico e desafiam pesquisadores a discuti-las e aprofundá-las. Esse artigo, escrito há mais de 20 anos, está bastante adequado ao título, a julgar pelas 1.512 citações registradas no Google Scholar até julho de 2009. Ao abordar a inovação como um processo interativo entre produtores, usuários, universidades e governo, Lundvall resgata a dimensão social da mudança tecnológica, que era em grande medida negligenciada pela teoria econômica convencional, abrindo caminho para uma nova trajetória de pensamento sobre inovação.

Bengt-Åke Lundvall foi vice-diretor da Divisão de Ciência, Tecnologia e Indústria da OCDE e é atualmente professor de economia da universidade dinamarquesa de Aolborg. Junto com Luc Soete, ele iniciou a rede global de pesquisas GLOBELICS, que vem estimulando estudos econômicos e sociais da ciência e tecnologia associados a aprendizado tecnológico, competitividade internacional, emprego e políticas públicas para sistemas nacionais de inovação.

A construção teórica do Sistema Nacional de Inovação foi compartilhada com Chris Freeman e Richard Nelson. Tais autores precederam Lundvall na crítica à teoria econômica neoclássica, devido a sua incapacidade de incorporar e explicar adequadamente o fenômeno da inovação. Lundvall reforça essa crítica argumentando que, ao colocar o mercado como centro da dinâmica econômica, a microeconomia tradicional tende a focar em decisões feitas com base em um determinado montante de informações estáticas. Ele considera que o tipo de informação necessária para inovar está em permanente mudança, sendo, portanto, necessário focar no processo de aprendizado contínuo. Em outras palavras, considerando que o processo de mudança tecnológica é extremamente dinâmico, o importante é analisar como os agentes econômicos administram o fluxo e não apenas um dado estoque de conhecimento.

Nesse artigo Lundvall introduz o conceito de "economia do aprendizado" que foi mais bem desenvolvido na década de 1990 em colaboração com Björn Johnson (Lundvall & Johnson, 1994). Segundo eles, o aprendizado interativo ocorre tanto entre pessoas quanto entre empresas socialmente inseridas no contexto institucional e cultural de um sistema de inovações. O conceito original de economias de aglomeração foi desenvolvido na década de 1950 por François Perroux, com base na constatação de que polos industriais geralmente surgem em torno de uma aglomeração urbana importante, ao longo das grandes fontes de matérias-primas ou nos locais de passagem e fluxos comerciais significativos. Lundvall faz uma nova leitura do processo de desenvolvimento ao considerar que, na economia do século XXI, o fator-chave para a criação de polos de desenvolvimento não seria os encadeamentos industriais, mas sim a capacidade local de aprender e inovar em diferentes áreas do conhecimento. Ele reconhece que a noção de sistema de inovação foi inspirada nos sistemas de produção, organizados como uma alternativa híbrida entre o mercado e a grande corporação vertical.

O caráter social da inovação é dado pelo entorno institucional da atividade inventiva, pela capacitação tecnológica local e principalmente pelos aspectos socioculturais dos agentes envolvidos. Esse ambiente "holístico" foi chamado de Sistema Nacional de Inovações, embora o autor reconheça que os sistemas de inovações não sejam necessariamente nacionais. Apesar de não elaborar muito o conceito de SNI nesse artigo, observa-se que há uma progressiva construção sobre seus trabalhos anteriores, em que o autor desenvolve o conceito de inovação como um processo essencialmente interativo, no qual a qualidade do ambiente local (ou nacional) cumpre um papel decisivo. A interação entre esses dois temas fica mais evidente em seu livro de 1992, *National Systems of Innovation: towards a theory of innovation and interactive learning*.

Lundvall critica a teoria dos custos de transação de Oliver Williamson por considerar implicitamente as inovações em produto como uma exceção e não como regra fundamental do funcionamento do sistema capitalista. Segundo Williamson, mercados caracterizados por um pequeno número de agentes, incertezas, racionalidade limitada e comportamentos oportunistas tendem a se tornar hierarquias. Nesse ambiente haveria pouco espaço para a cooperação tecnológica, pois a assimetria de informações levaria à integração vertical. Ao considerar o aprendizado como um processo predominantemente interativo e socialmente inserido, Lunvall rejeita tal visão por reduzir a decisão de inovar a uma mera decisão interna da firma, sem levar em consideração seu contexto institucional e cultural. Sua teoria transcende o pensamento econômico, ao buscar interfaces com a sociologia, que daria suporte à visão de "aprendizado por interação".

Por outro lado, como argumenta Grassi,[1] a abordagem de Lundvall não destaca de forma clara a possibilidade de surgimento de comportamentos oportunistas em relações de cooperação e as diferentes formas dos agentes lidarem com eles. A teoria dos custos de transação é rejeitada pelo seu caráter estático, mas Lundvall não oferece uma alternativa para lidar com a questão do oportunismo. Inversamente, são ressaltados os comportamentos de confiança que constituem um ativo intangível fundamental para a cooperação e o aprendizado. Redes de firmas duráveis envolveriam um conjunto de formas de governança multilaterais, nas quais evoluem a reciprocidade informal e o desenvolvimento de confiança mútua. Assim, ele admite implicitamente que as oportunidades de ganhos com interação se tornam muito superiores aos eventuais custos de transação que possam ocorrer.

Os mais céticos podem achar que Lundvall age como Poliana, mas podemos argumentar a seu favor que nenhuma empresa, por maior e mais competente que seja, consegue hoje inovar significativamente de forma isolada. O benefício da cooperação é potencialmente tão importante, que a indústria tem incentivos suficientes para encontrar formas de mitigar os custos de transação.

Outra polêmica gerada pelo artigo é sobre o caráter nacional do sistema de inovações. A Internet, que ainda não estava operacionalizada na época em que Lundvall escreveu esse artigo, facilitou enormemente as formas de cooperação internacional, tornando mais tênues as fronteiras nacionais do conhecimento. O advento de novas formas de cooperação, a exemplo da inovação aberta e do *software* livre e exemplo da dimensão global do conhecimento. Embora Lundvall reconheça a tendência à internacionalização da produção tecnológica, ele acredita que isso não remove os padrões idiossincráticos de especialização na produção e no

1 Robson Grassi, "Capacitações dinâmicas, coordenação e cooperação interfirmas", Estudos Econômicos, São Paulo, v.36, n.3, p.611-635, jul.-set., 2006.

comércio internacional. Como evidência, argumenta que a Dinamarca se tornou um dos países mais competitivos em equipamentos e tecnologias para a pecuária leiteira, porque é um expressivo produtor de leite, fato que abriu caminho para a relação usuário-fornecedor. O aspecto sociocultural de cada país tende a ser único e a excelência de certas instituições nacionais é determinante para a inovação.

A visão de Lundvall pode também indicar um caminho para a política industrial e tecnológica brasileira. Podemos constatar que o país, apesar de desenvolver políticas tecnológicas em diversas áreas industriais nos últimos 30 anos, só logrou excelência tecnológica em setores econômicos em que havia necessidade de uma forte relação local usuário-fornecedor. A Embrapa se tornou líder mundial em tecnologias para a agricultura tropical, porque havia uma demanda latente por insumos e cultivares apropriados às condições climáticas do cerrado brasileiro, que não era atendida adequadamente pela tecnologia disponível internacionalmente. Outro caso emblemático é o desenvolvimento de tecnologias de exploração de petróleo em águas profundas pela Petrobras. Como a maioria das petroleiras globais dispunha de reservas de petróleo em terra ou águas pouco profundas, não havia soluções adequadas para a extração de óleo na plataforma continental brasileira. Assim, um sistema de inovações nacional precisou ser desenvolvido para fazer frente às necessidades tecnológicas locais. Em outras áreas industriais, em que a demanda nacional por tecnologia não se diferenciava do resto do mundo, a exemplo da eletrônica e da química fina, o esforço tecnológico nacional teve pouco êxito. Como argumenta Carmem Feijó, o desenvolvimento de complementaridades apresenta efeitos de demanda e também de oferta. Efeitos de demanda são explicados pelo mecanismo do multiplicador keynesiano – na ausência de interação entre firmas e entre setores, parte do aumento de demanda é "vazada" para o exterior, aumentando a propensão marginal a importar da economia.

Por fim, cabe lembrar que o caminho proposto por Lundvall de investir na capacitação e no aprendizado interativo requer políticas governamentais sólidas, tanto para gerar as instituições de apoio necessárias ao desenvolvimento tecnológico como para estimular a busca de soluções para problemas locais que não são bem resolvidos pelo mercado. Em um país com tantos problemas econômicos, sociais e ambientais idiossincráticos, a sugestão implícita de Lundvall parece muito interessante para orientar nossa política tecnológica.

Technical Change and Economic Theory

Edited by

Giovanni Dosi
Christopher Freeman
Richard Nelson
Gerald Silverberg
Luc Soete

Pinter Publishers, London and New York

17 Innovation as an interactive process: from user–producer interaction to the national system of innovation

Bengt-Åke Lundvall
Institute for Production, Aalborg University, Aalborg

Introduction

In this chapter the focus is upon the interactive of the process of innovation.[1] The analysis takes as its points of departure two important characteristics of an industrial economy: the highly developed vertical division of labour and the uniquitous and all-pervasive character of innovative activities. It follows that a substantial part of innovative activities takes place in units separated from the potential users of the innovations.[2]

Here we shall argue that the separation of users from producers in the process of innovation, being 'a stylized fact' of a modern industrial society (capitalist or socialist), has important implications for economic theory. When we focus upon innovation as an interactive process, theoretical and practical problems tend to present themselves differently than in mainstream economic theory.

The interactive aspects of the process of innovation can be studied at different levels of aggregation. In the first part of the chapter we discuss 'the microeconomics of interaction'. In the second part we present some preliminary ideas on how a model of a national system of innovation can be developed.

The micro-foundation: interaction between users and producers

In standard microeconomics the agents—firms and consumers—are assumed to behave as maximizers of profits and utility. Perfect competition with numerous buyers and sellers, the flow of information connecting them, encompassing nothing but price signals, is the normative and analytical point of reference of the theory. Monopolistic structures and complex client relationships are regarded as deviations from this normal and ideal state.

The kind of 'microeconomics' to be presented here is quite different. While traditional microeconomics tends to focus upon decisions, made on the basis of a given amount of information, we shall focus upon a *process of learning*, permanently changing the amount and kind of information at the disposal of the actors. While standard economics tends to regard optimality in the allocation of a given set of use values as the economic problem, *par préférence*, we shall focus upon the capability of an economy to produce and diffuse *use values with new characteristics*. And while standard economics takes an atomistic view of the economy, we shall focus upon the *systemic interdependence* between formally independent economic subjects.

Product innovations in a pure market?

In an economy characterized by vertical division of labour and by ubiquitous innovative activities, a substantial part of all innovative activities will be adressed towards users, outside the innovating units. In such an economy successful innovations must be based upon knowledge about the needs of potential users, and this knowledge is as important as knowledge about new technical opportunities (Freeman, 1982, p. 124, *passim*). When an innovation has been developed and introduced, it will diffuse only if information about its use value characteristics are transmitted to the potential users of the innovation. Within organizations and firms, this constitutes an intra-organizational problem, to be solved through interaction and information exchange, involving different individuals and departments belonging to the same organization.

Here, however, the focus will be upon those innovative activities which are oriented towards new products to be presented to a market. For simplicity, we shall label such innovations 'product innovations', keeping in mind that they might constitute new materials and new process equipment, as well as new consumer products. Further, we shall not primarily treat innovations as single events. By using terms such as 'the process of innovation' and 'innovative activities', we indicate that the traditional separation between discovery, invention, innovation and diffusion might be of limited relevance in this specific context.[3]

How can the mutual information problem be solved when the producer and the user are separated by a market? If the market is 'pure', in the neoclassical sense, the problem must remain without a solution. In such a market the only information exchanged relates to products already existing in the market and it contains only quantitative information about price and volume. Anonymous relationships between buyer and seller are assumed. In such a market the innovating units as well as the potential users will operate under extreme uncertainty. Producers have no information about potential user needs and users have no knowledge about the use-value characteristics of new products. If the real economy was constituted by pure markets, product innovations would be haphazard and exceptional.

It is interesting to note that the pure market—hailed by some neoclassical economists for its ability to establish an efficient allocation of resources on the basis of very limited amounts of information—forms an environment hostile to innovative activities, and that product innovations would be all but absent in a capitalist economy characterized by perfect competition. At an abstract level, a socialist economy would be expected to overcome this crucial information problem more easily through a planning mechanism, taking into account the need for the exchange of qualitative information. According to a recent study of innovations in the Soviet Union, however, the lack of efficient user–producer interaction seems to be a major problem in the 'real existing socialist countries' (Amann and Cooper, 1982).

Anne P. Carter (1986) has recently pointed to the neglect of product innovations in production models as a general and serious weakness. But this neglect might be said to be fully consistent with the microeconomic assumption of pure markets as the norm. In a world where all products were characterized by constant use-value characteristics, pure markets could survive, and those pure markets would tend to reproduce the existing set of use values. Introducing product innovations into economic models cannot but erode the traditional concept of the pure market.

Product innovations and transaction costs

One well-established alternative conception of the process of exchange is the transaction cost approach presented by Oliver E. Williamson (1975). What are the implications of product innovations if we take this approach as our point of departure? According to Williamson, markets characterized by small numbers, uncertainty, limited rationality and opportunistic behaviour will tend to become hierarchies. High transaction costs will induce vertical integration. A market where product innovations were frequent would involve true uncertainty at both sides of the market, the uncertainty emanating not from the external conditions for transaction but from qualitative change in the commodity itself. It would also imply what Williamson calls 'informational impactedness'—an uneven distribution of information. The innovating unit would, typically, have much more, and more certain, information about the use value characteristics of the new product than the potential user.

In the Williamson framework, as in the neo-classical world, we would expect product innovations to be exceptional. They should become internalized and transformed into process innovations through vertical integration.

It is, of course, quite difficult to measure the proportion of innovative activities directed towards product innovations in the sense of the concept used here. One of the few systematic innovation data banks is the one developed at the Science Policy Research Unit, Sussex University. Among the more than 2,000 important post-war innovations reported in Pavitt (1984), more than a half were developed for outside firms (ibid., p. 348). OECD data on the allocation of R & D activities confirm that product innovation is as important a phenomenon as process innovation in the OECD area.

Thus neither standard microeconomics nor the original transaction cost approach are easily reconciled with the stylized facts of a modern industrial economy. In order to explain the actual importance of product innovations we must take a closer look at the (assumed) market–hierarchy dichotomy.

The organized market as a solution?

If all transactions in the real world took place either in 'pure markets' or in 'pure organizations', innovative activities would be less frequent than they are, and they would mainly take the form of process innovations. The fact that product innovations are frequent in the real world demonstrates that most real markets are 'organized markets' rather than pure markets. The actually observed relative efficiency of the capitalist system, in terms of innovative behaviour, can only be explained by the fact that the invisible hand of the pure market economy has been replaced by bastard forms, combining organization elements with market elements.

The organized market is characterized by transactions between formally independent units and by a flow of information on volume and price. But it also involves relationships of an organizational type. Those relationships might involve flows of qualitative information and direct cooperation. They might take a hierarchical form, reflecting that one party dominates the other, by means of financial power or of a superior scientific and technical competence. As we shall see, a purely hierarchical relationship will, however, often prove insufficient. Mutual trust and mutually respected codes of behaviour will normally be necessary in order to overcome the uncertainty involved.[4]

User–producer interaction in the process of innovation

We shall now take a closer look at the specific forms of user–producer interaction in relation to the process of innovation. The producer will have a strong incentive to monitor what is going on in user units. First, process innovations within user units might be appropriated by producers or represent a potential competitive threat. Second, product innovations at the user level may imply new demands for process equipment. Third, the knowledge produced by learning-by-using can only be transformed into new products if the producers have a direct contact to users. Fourth, bottlenecks and technological interdependencies, observed within user units, will represent potential markets for the innovating producer. Finally, the producer might be interested in monitoring the competence and learning potential of users in order to estimate their respective capability to adopt new products.

The user, on the other hand, needs information about new products, and this information involves not only awareness but also quite specific information about how new, use-value characteristics relate to her/his specific needs. When new user needs develop—for example, when bottleneck problems occur—the user might be compelled to involve a producer in the analysis and solution of the problem. This can only be done successfully if the user has a detailed knowledge about the competence and reliability of different producers.

When complex and specialized equipment is developed and sold to users, there will be a need for *direct cooperation* during the process of innovation. The cooperation is not a single act but takes place at different stages of the process (Rothwell and Gardiner, 1985). First, the user may present the producer with specific needs to be fulfilled by the new product. Second, the producer might install it and start it up in cooperation with the user. At this stage, the producer might offer specific training to the user. After the product has been adopted there might follow a period where the producer would have obligations regarding repair and updating of the equipment.

The uncertainty involved in this kind of transaction will be considerable. Not only is the user buying a product with unknown characteristics. He is also buying the cooperation of an external party for a future period. It should be obvious that the room for an opportunistic producer to cheat is considerable. Conversely, this implies that 'trustworthiness' becomes a decisive parameter of competition. If a user has a choice between a producer known for low-price and technically advanced products, but also for having a weak record in terms of moral performance, and one well known for trustworthiness, the first will be passed by. This implies limits to opportunistic behaviour. Those limits are reinforced when users pool their information about the reliability of different producers.

The exchange of information between user and producer also involves uncertainty and room for cheating and disloyal behaviour. The user must disclose her/his needs to the producer in order to get workable solutions. The producer has an interest in disclosing the full capacity of his product and in giving the user insight into his technical competence as a potential cooperator. But in both cases a full disclosure might be abused by the other party. Information might be spilled to competitors and each party may invade the market of the other party. Again, the abuse can only be restrained if codes of behaviour and mutual trust form an element of the relationships. Without any such restraints, transaction costs would become prohibitive and vertical integration would become a necessary outcome.

How strong is the element of organization?

The element of organization might be quite weak in certain markets. If the product is simple, its use-value characteristics changing but slowly, and the expenditure for its procurement forms a negligible part of the user's budget, the market might become quite 'pure'. When its use-value characteristics are changing rapidly, are complex and the product is expensive, the element of organization will be strong. The former type of goods will, typically, be developed by the producer alone and bought 'off the shelves', while the latter will be developed in an interaction between the user and producer, and the act of exchange will involve direct cooperation and exchange of qualitative information.

The flow of information

In markets where the element of organization is strong, the flow of information might be analysed in terms parallel to those applied in the theoretical analysis of pure organizations. Here we shall use some elements from a conceptual framework developed by Kenneth Arrow (1974). The flow of information can only take place if there exist *channels of information* through which the message can pass. Further, a *code of information* is necessary in order to make the transmission of messages effective. The establishment of channels of information may, according to Arrow, be regarded as parallel to a process of investment in physical capital. It is a time-consuming process involving costs. The development of a common code is also time-consuming and involves learning. The more the code is used in transmitting information, the more effective it becomes. 'Learning-by-interacting' increases the effectiveness of a given set of channels and codes of information.

The selectivity of user–producer interaction

The organizational element will not link every single producer to every single user—here we disregard pure monopolistic and pure monopsonistic situations. Normally, each producer will have a close interaction with a subset of all potential users and each user will be attached to only one, or a small subset of all potential producers. This selectivity reflects the need to develop non-economic relationships of hierarchy and mutual trust. It also reflects the need to develop effective channels and codes of information.

User–producer relationships in time

It takes time to develop selective relationships involving elements of hierarchy and mutual trust. It also takes time to develop effective channels and codes of information. Once those relationships have become established, it will not be cost-less to sever the connections. Inertia—a general resistance to change and risk aversion—combines with rational motives in reinforcing existing user–producer relationships. *Ceteris paribus*, the user will prefer to trust producers, known from her/his own experience, rather than getting involved with a new producer. The investment in information channels and codes will be lost if the old relationships are severed and new investment in the creation of new relationships will be required. Therefore user–producer relationships will tend to become enduring and resistant to change. Only if the costs of keeping the existing relationships going are apparent, or the economic incentives offered by new relationships are substantial, will a reorganization of the markets take place.

User–producer relationships in space

The user–producer relationship is defined in 'economic space' coupling units, close to each other, in an input–output system. The selective user–producer relationships will involve units more or less distant from each other in geographical and cultural space. The importance of distance will vary with the type of innovative activity involved. When the technology is standardized and reasonably stable, the information exchanged may be translated into standard codes, and long-distance transmission of information can take place and involve low costs. Here, user–producer relationships involving units located far away from each other might be effective.

When the technology is complex and ever changing, a short distance might be important for the competitiveness of both users and producers. Here, the information codes must be flexible and complex, and a common cultural background might be important in order to establish tacit codes of conduct and to facilitate the decoding of the complex messages exchanged. The need for a short distance will be reinforced when user needs are complex and ever changing.

When the technology changes rapidly and radically—when a new technological paradigm (for a discussion and a definition, see Dosi, 1982) develops—the need for proximity in terms of geography and culture becomes even more important. A new technological paradigm will imply that established norms and standards become obsolete and that old codes of information cannot transmit the characteristics of innovative activities. In the absence of generally accepted standards and codes able to transmit information, face-to-face contact and a common cultural background might become of decisive importance for the information exchange.

Vertical integration as a means of overcoming geographical and cultural distance

The development of transnational capital and of vertically integrated firms operating all over the world reflects that 'organizational proximity' may overcome geographical and cultural distance. But vertical integration may have its price. It tends to exclude integrated units from the interaction with producer units and user units outside the integrated firm. Such independent firms will tend to guard themselves against an open information exchange with a vertically integrated unit. As users, they risk to get less efficient technology than their integrated counterpart and competitor. As producers, they fear that the know-how built into their product innovations will become expropriated by the integrated user and transferred to an integrated competing producer.

Also, the vertically integrated units may prove to be more rigid and less susceptible to new technical opportunities and new user needs than the parties operating in an organized market. The tendency towards vertical integration is strong, but there are also certain counter-tendencies at work. The trade-off between saved transaction costs and the loss in terms of a more narrow interaction with external parties will differ between different parts of the economy. It will, among other things, reflect the state of the technology and the character of the process of innovation.

User and producer characteristics and the innovative potential of interaction

Not all user–producer relationships promote innovative activities. Being closely linked to conservative users having weak technical competence might be a disadvantage for a producer, and vice versa. The innovativeness and the competence of users and producers are important qualities which might stimulate the other party. The degree of standardization among users might also be important. Being dependent upon a set of users with very diversified needs might make it difficult for the producer to accumulate experience and to exploit scale economies.

The effectiveness of the user–producer relationships grows with time. As a subset of users and producers gets more experience from interaction, the elements of hierarchy and mutual trust are strengthened and the exchange of information becomes more open. The code of information becomes more effective in transmitting complex messages related to the process of innovation. As we shall see below, this 'effectiveness' does not, however, guarantee *efficiency* if the criterion is user satisfaction at a low cost. The negative side is inertia and resistance to change.

'Unsatisfactory innovations'

Traditional welfare economics tends to disregard innovative activities. It analyses the allocation of a given set of use values with given characteristics. Nor are the concepts used easily adapted to a normative analysis of the process of innovation. There is no point in asking how actual innovations deviate from 'an optimum'. Innovations not yet conceived are not known to us, and therefore we do not have any well-defined points of reference for such an analysis.

In certain instances it might, however, be possible to demonstrate how innovative activities and technological trajectories deviate systematically from user needs. When deviations cannot be ascribed either to a lack of technical opportunities or to an unwillingness among users to pay the costs for an adaption to the user needs, we might label the innovations 'unsatisfactory'.

When the user–producer relationships are characterized by a strong dominance of producers in terms of financial strength and technical competence, such deviations become more likely. In the field of consumer goods the producer dominance is very accentuated. The producer organizes both the process of innovation and the information exchange with users. In this field we should expect 'unsatisfactory innovations' to be frequent (Freeman, 1982, p. 202ff). A pattern of dominance and hierarchy might be found also when the user is a professional organization. If a few big firms produce scientifically based, complex and systemic products for a great number of small, independent user units—each with a low technical and scientific competence—producers will dominate the process of innovation and the likelihood of unsatisfactory innovations becomes great. In a study of the Danish dairy industry, such a pattern, resulting in 'hyper-automation', was found to characterize the relationships between producers and users of dairy equipment (Lundvall *et al.*, 1983).

In such situations coordination among users might develop and resources might be pooled in order to develop a counter-competence. Such a co-ordination will often be more difficult to make efficient when the users are consumers than when they are professional units. Government regulation or government support to user organizations might be necessary in order to rectify an unsatisfactory trajectory in consumer technology.

Another background for unsatisfactory innovations might be inertia in user–producer relationships and the 'effectiveness' of already established channels and codes of information. In a historical period characterized by the development and introduction of basic radical innovations, the rigidity of the existing set of user–producer relationships tends to become manifest. A basic radical innovation will often be produced by a new sector with weak forward linkages. The potential users of the innovation will be found in most parts of the economy, and those users will have backward linkages to producers, having little experience and competence in relation to the new technology. Existing user–producer networks will prove to be tenacious and it will take considerable time for a new network to become established. During such a period of transition, productivity might be stagnating, while new technological opportunities seem to flourish.

Here, the problem is not only specific unsatisfactory technical innovations, but rather a general 'mismatch' in the whole economy. Christopher Freeman and Carlota Perez (1986) have discussed how a 'technological revolution', based upon information technology, might provoke mismatch problems related not only to capital and labour but also to the existing socio-economic institutional set-up. The rigidity of user–producer relationships might be regarded as one important aspect of this last type of mismatch. It is important because it has its roots in the very core of the market system, in markets producing innovations. Policy strategies, putting all the emphasis upon flexibility through market regulation and minimizing the role of government in the process of adjustment, seem to be somewhat off the point when rigidities are produced and reproduced within the markets themselves.

Is innovation induced by supply or by demand?

One of the classical disputes in innovation theory refers to the role of demand and supply in determining the rate and direction of the process of innovations (Mowery and Rosenberg, 1979; Freeman, 1982, p. 211). The user–producer approach puts this question in a new perspective. On the one hand, it demonstrates that demand does play an important role in the process of innovation. On the other hand, it puts the emphasis more upon the *quality of demand* than upon demand as a quantitative variable. The very substantial user expenditure channelled into the demand for private transportation has not resulted in radical product innovations in the automobile industry. Conversely, very competent and demanding users have provoked radical innovations in areas where the volume of expenditure has been miniscule. The role of users in relation to the development of new scientific instruments is illustrating in this respect.

Individual innovations might appear as unrelated to user needs, such as innovations emanating from science. In the second part of this chapter it will be argued that even science has its users and that many innovations, appearing as purely supply-determined, have their roots in a user–producer interaction placed early in the chain of innovation. In this perspective *general* statements about the role of 'demand' and 'supply' do not seem very relevant.

Some implications for industrial and technology policy

The fact that technology is influenced by the demand side has been used to argue for a *laissez-faire* technology policy. If demand is provoking the innovations called for, there is no need for state intervention. Those arguing that the supply side plays the dominating role will often recommend government support to R & D activities and education, combined with an active manpower policy. The implications of a user–producer approach are somewhat more complex.

First, technology policy should take into account not only the competence and innovativeness of units placed early in the chain of innovation. The lack of competence of users and the tendency of producers to dominate the process of innovation might be as serious a problem as a lack of competence on the producer side. Even when the state itself acts as a user, one will often find that the competence will be too weak and this might result in 'unsatisfactory innovations'. Two Danish case studies, looking into the role of local government as user of waste-water technology and office technology, demonstrated how a lack of local user competence had a negative effect upon the systems developed and used (Gregersen, 1984; Brængaard *et al.*, 1984).

Second, government may intervene, directly or indirectly, in relation to the establishment and restructuring of patterns of user–producer relationships. In a period characterized by gradual technical change and incremental innovations, a national government might sustain national and international user–producer linkages which already exist. It might also support the establishment of specific organisations, intermediating between groups of users and groups of producers, pooling information, and thereby stimulating the production and diffusion of innovations.

In a period characterized by radical innovations and a shift in technological paradigm, the task of government becomes vastly more complex and important. In such a period, there is a need for a transformation of the existing network of user–producer relationships. The inertia originating in the organized markets will at the national level be supported by the political power of strong interest groups, closely associated with the prevailing structure. The difficult task for government will be to stimulate the renewal, or severance, of well-established user–producer relationships and the establishment of new relationships.

Standard microeconomics and the user–producer approach

Some of our results can now be confronted with the kind of microeconomic theory presented in standard textbooks. We make the following observations:

- The element of organization will be different, in terms of content and strength, between different markets and it will change over time. Some markets will be more susceptible to an analysis based upon the concepts of optimizing agents acting at arms-length distance than others. This raises some doubt about the intentions to construct one single model of micro-behaviour, assumed to be generally valid for all markets—a problem discussed by Kornai (1971, p. 207ff).
- The standard approach will be most relevant when technological opportunities and user needs remain constant. When product innovations are continuously provoked by changing technological opportunities and users needs, it is no longer meaningful to assume optimizing behaviour. 'Short-run' decisions, by producers to become involved in certain lines of innovating activities, and by users to choose among new products, will be characterized by true uncertainty, as will, *a fortiori*, 'long-run' decisions, referring to the establishment of (and investment in) new relationships and information channels.
- Standard microeconomics regards technical change as an exogenous process and its outcome as technical 'progress', indicating growing efficiency. In organized markets the existing set of user–producer relationships may produce technological trajectories, deviating systematically from what is 'satisfactory', even when users and producers act according to profit motives.
- In standard microeconomics, changes in relative prices will influence the decisions taken by users and producers automatically and instantaneously. A world characterized by organized markets will be sluggish in this respect. The existing set of user–producer relationships and the continuous qualitative change in products will reduce the responsiveness to changes in relative prices.

National systems of innovation

In the first part of this chapter, we found that the microeconomic framework, as presented in standard textbooks, is not easily reconciled with certain stylized facts of the modern economy. A highly developed vertical division of labour, when combined with ubiquitous innovative activities, implies that most markets will be 'organized markets' rather than pure markets. In this second, and final, part we shall sketch some of the implications of our micro-approach for the national and international level. Elements of a model of a national system of innovation will be introduced.

The subdisciplines in economics most relevant in this context are theories of economic growth and international trade. Standard growth models are developed under the assumption of a closed economy. This is a natural assumption in so far as the models regard new technology as falling 'as manna from heaven' and as equally accessible for all actors, sector, regions and nations. Standard foreign-trade theory assumes labour and capital to be perfectly immobile and commodities to be perfectly mobile across national borders. It has the assumption of perfectly free and mobile technology in common with standard growth theory.

This last assumption is at odds with what can be observed in the real world, where some countries establish themselves as technological leaders, generally or in specific technologies, while others tend to lag behind. According to the user–producer approach, geographical and cultural distance is a factor which may impede the interaction between user and producers. This might contribute to an explanation of why different national systems display different patterns of development.

The nation as a framework for user–producer interaction

The tendency towards internationalization of trade, capital and production has been strong during the post-war period. Some would even argue that nations tend to become obsolete as economic subjects. But this process of internationalization has not wiped out idiosyncratic national patterns of specialization in production and international trade. The fact that Denmark is strongly specialized in dairy machinery, Sweden in metal-working and wood-cutting technology, and Norway in fishery technology cannot be explained by the general factor endowments in those countries. Rather, we should look for the explanation in the close interaction between producers of such machinery and a competent and demanding domestic user sector (Andersen *et al.*, 1981).

Interaction between users and producers belonging to the same national system may work more efficiently for several reasons. Short geographical distance is part of the explanation; more important may be a common language and the cultural proximity. It is thus interesting to note that firms in the Nordic countries tend to regard all the Nordic countries as their 'home market'. This might reflect that those nations have very much in common in terms of culture and social organization (Dalum and Fagerberg, 1986).

Another factor of importance is, of course, national government. The role of government in relation to the process of innovation has been seriously underestimated according to recent historical studies (Yakushiji, 1986). Besides more direct interventions in relation to specific innovations, government imposes standards and regulations, making domestic interaction more efficient. In important instances the state intervenes directly in the network and supports existing user–producer relationships.

The fact that national economies have idiosyncratic technological capabilities reflects that international transfers of technology is neither cost-less nor instantaneous. Some parts of knowledge can be embodied in traded commodities, while other parts are embodied in the labour force. The limited mobility of labour across national borders can partly explain why technology is not easily transferred internationally. The structure of the national systems of production and innovation is a product of a historical process and it cannot be transferred as easily as 'factors of production'. It might be here that we find the most fundamental restriction to international learning and international transfer of technology.

The importance of nations as frameworks for user–producer interaction does not rule out transnational interaction, however. In some industries and technologies the required scale of the R & D effort is so enormous that not even the biggest of the transnational firms can afford to go alone when developing a new product. This is the case for civil aircraft, space technology and nuclear power. Here the pattern of user–producer interaction transcends national borders. But even in these areas, national interests related to international competitiveness and military goals put certain limits to the actual cooperation taking place, according to recent case studies (OECD, 1986).

Applying a user–producer perspective to international relations brings forward the structural interdependency, characterizing the process of innovation within and between nations. Onto this background we shall sketch the outlines of 'a national system of innovation'. Earlier research involving international comparisons of innovative capabilities have demonstrated important international differences at the micro level, in terms of management strategies and firm behaviour, sometimes taking into account differences in the environment of firms, financial institutions and labour relations, for example. Such studies, useful as they are, might underplay the importance of the structure of the full system of innovation, however. When the process of innovation is regarded as the outcome of a complex interaction, it is obvious that the whole system might be more than a sum of its parts.

The concept of the national system of innovation will be developed step by step, using earlier contributions on systems of production and on the division of labour within systems of innovation as some of its elements.

National systems of production

While Anglo-Saxon Industrial Economics tends to regard national economies as 'a bunch of industrial sectors', the French tradition has been more oriented towards the systemic interdependence between different parts of the economy. Verticals of production of 'filières', encompassing all stages of production from raw materials to final products, are important units of analysis in this tradition (de Bandt and Humber, 1985). A broader concept, also bringing in public agencies and financial institutions, industrial subsystems or 'mésosystèmes industriels', has recently been developed and proposed as the units, most adequate, for industrial policy (de Bandt, 1985).

An even more ambitious approach, presented by some French marxists, and inspired by the work of François Perroux, defines 'the national system of production' as a unit of analysis. The national industrial system is divided into a small number of sections, defined by the economic function of the output and by its sector of use (investment goods, semi-manufactured goods and consumer goods) (GRESI, 1975). Some of the contributions in this tradition assume the section producing investment goods for the production of investment goods to be the strategic one for economic growth and development. National systems, having a strong position in this area, will tend to have a strong international competitiveness and vice versa. The national system of production is thus not assumed to be a closed system. On the contrary, it is the specific degree and form of openness which determines the specific dynamics of each national system of production.

Production and innovation

In order to judge the relevance of this model it is necessary to look into the relationship between the process of production and the process of innovation. These processes differ in important respects but they are also mutually interdependent.

Production is a repetitive process where routines tend to develop. The flows of goods and services between different subsystems can—if use-value characteristics remain constant—easily be quantified in terms of value and volume. The process of innovation might be continuous and cumulative, but it will always have a unique element, stressing the importance of creativity, as opposed to routine decision-making. The flows between the subsystems will be complex and systemic information, difficult to translate into quantitative terms.

The interdependency between production and innovation goes both ways. On the one hand, learning taking place in production—as 'learning-by-doing' or as 'learning-by-using'—forms an important input into the process of innovation. 'Learning-by-interacting' will, typically, take place between parties, linked together by flows of goods and services orginating from production (this is a prerequisite for user–producer relationships to become enduring and selective). On the other hand, the process of innovation might be the single most important factor restructuring the system of production, introducing new sectors, breaking down old, and establishing new, linkages in the system of production.

This interdependency between production and innovation makes it legitimate to take the national system of production as a point of departure for defining a system of innovation. But the division of labour in the system of innovation is not just a reflection of the division of labour in the system of innovation. Some parts of the production system will be more productive in terms of innovations while others primarily will be users of innovations developed by others. This is documented in some recent contributions to innovation theory.

The vertical division of labour in the national system of innovation

Most innovation studies, focusing upon vertical interaction, have put the emphasis upon the division of labour in the process of innovation. The pioneering studies of the sector producing scientific instruments, made by von Hippel (1976), demonstrated that process innovations were often developed by the sector itself. Even when independent producers were involved the users played an important active part in the process of innovation.

In Pavitt (1984), a taxonomy, referring to different types of industries according to their respective role in the process of innovation, is presented. Using a data base for important UK innovations, containing information of origin and address of each innovation, three different types of sectors were identified—supplier-dominated, production-intensive and science-based. This taxonomy and the further subdivisions made are extremely useful in defining the division of labour within the national system of innovation.

Flows and stocks in the national system of innovation

Earlier we pointed out that the flows within the system of innovation take the form of complex and systemic information—messages difficult to translate into quantities. This is also true for the stocks of the system. Knowledge, scientific as well as know-how and tacit knowledge, is difficult to measure. Other important 'stocks' may be the inventiveness and creativity of individuals and organizations and those are even more difficult to assess in quantitative terms.

In standard economics there is a strong tendency to define scientific analysis as synonymous with the establishment of quantitative and mathematical models. If we accepted this dictum, important aspects of the national system of innovation would be regarded as being outside the realm of economic science. As pointed out by Georgescu-Roegen (1971, p. 316ff), this ideal of science is not uncontroversial, however. It reflects an epistomology imported from Newtonian physics. Georgescu-Roegen demonstrates that 'dialectical concepts'—along with arithmomorphic concepts—must be a part of any science analysing change.

Further, there have been different attempts to develop a quantitative analysis of the flows within national systems of innovation. As a matter of fact, the already mentioned study by Pavitt (1984) may be regarded as a quantitative approach using the number of 'important UK innovations' as the unit of account. Another interesting contribution in this field is Scherer (1982). Here a detailed input–output matrix for the US industrial system is developed on the basis of information gathered on patenting and R & D activities.

In both of these papers it is the industrial system which is at the centre of the analysis. This is natural in so far as most innovations emanate within this system. But when we look at the system of innovation from a user–producer perspective it becomes interesting to take a closer look at the interfaces between industry and the academic community and at the interfaces between industry and some of the 'final users' of industrial innovations—workers, consumers and the public sector.

In a recent paper by Nelson (1986) the division of labour in, and performance of, the US system of innovation is discussed. It is demonstrated that universities and other public institutions involved in the production of science are important parts of this system, acting in a way which makes them complementary to the innovative activities going on in the private sector. It is obvious that any model of a national system of innovation must take into account the interaction between universities and industry.

Science and technology in a user–producer perspective

In the first part of this chapter we focused mainly upon the interaction between firms producing goods and services. The user–producer perspective might, however, be applied to early stages in the chain of innovation—basic research, applied research and developmental activities. It is almost built into the definition of 'basic research' (as non-applied) that it should take place without any specific purpose or address. This picture is too simple, however. Even pure science, as mathematics and logics, has its users, and the agenda of science will often be determined by users in applied science. Also in this area the innovativeness and competence of users may influence the rate and direction of scientific discovery. In a case study referring to Bell Telephone Laboratories. Nelson (1962) has demonstrated the close interaciton between basic and applied research.

What separates pure science from technology is primarily the institutional framework. Science will, typically, be produced in universities according to an academic 'mode of behaviour', while technology primarily will be produced in private firms according to a profit-oriented 'mode of behaviour'. The academic mode will typically be characterized by non-pecuniary incentives—the 'search for excellency' will be a strong motive power (sometimes even combined with an urge to understand what is going on). The output of science will be widely dispersed because the world-wide diffusion of research results is a precondition for recognition of excellency (David, 1984). This mode of behaviour implies a different culture from the one predominating in profit-oriented firms. Norms, values and incentives are different, as well as the language and the codes of information used in the two spheres.

It is not surprising that the link between universities and industry has become a political issue. The growing recognition of the role of science in relation to technology and production has made it to a national priority to strengthen this link. The flourishing of 'Silicon Valleys', characterized by a close interaction between 'excellent' universities and high-technology firms in different parts of the world, has given the debate further impetus. In most OECD countries the establishment of 'sicence parks' and 'technopolises' has become a part of industrial policy.

The efforts made to integrate and subordinate academic activities in relation to industry may not be cost-less, however. If the academic mode of production is undermined and replaced by a profit-oriented mode of behaviour, where pecuniary incentives become more important and where secrecy regarding the output becomes more frequent, the academic mode of behaviour may lose one of its principal merits—its tradition for world-wide diffusion of knowledge. In the field of biotechnology this process seems already to have reached a critical level (Chesnais, 1986). National systems of innovation may temporarily become strengthened when universities become subordinated to industry. In the long run, the production and world-wide distribution of knowledge may become weakened.

Introducing the final users of technology into the system

The classical actors in innovation studies are individual entrepreneurs and the R & D laboratories of big firms. Secondary parts may be played by scientists and policy-makers. The user–producer approach points to the fact that 'final users' in terms of workers, consumers and the public sector may have a role to play in relation to innovation.

The fact that workers and consumers tend to be absent from the scene in most innovation studies reflects, to a certain degree, the reality of a modern industrial system. Both in planned and market economies the process of innovation tends to become a professionalized activity and workers and consumers tend to become passive beneficiaries or victims in relation to new technology, rather than subjects taking an active part in the process of innovation. It is, however, not self-evident that such a division of labour is 'natural' and appropriate. Active and competent final users might enhance the innovative capability of a national system of innovation.

Further, the actual participation of 'final users' may be underrated in the literature on innovation. Workers play an important part in the daily learning process taking place in production and many incremental innovations may be the product of skilled workers improving on the process equipment. Where workers are directly involved in the process of innovation, the outcome in terms of productivity and efficiency might be more satisfactory than when they are excluded from this process. Some studies of the Japanese experience seem to point in this direction.

Among consumers we find some interesting examples in the user clubs established in relation to specific brands of personal computers. Here private consumers act as professional users, developing new software in an interaction with producers of hardware and software. But for most consumer goods the interaction is organized exclusively by producers gathering information about, and manipulating, consumer needs. An interesting theoretical contribution giving consumer learning an important role in the overall development of the national economy is made by Pasinetti (1981), who maintains that the learning of new needs are of crucial importance for the maintenance of full employment. When productivity is growing and demand for existing consumer goods becomes satisfied, the learning of new needs by consumers is a necessary condition for avoiding 'technological unemployment'.

We have already pointed out the importance of the public sector as a final user in relation to technology policy. The most comprehensive and important historical example might be the military industrial complexes in the United States and the Soviet Union. In both these cases, the state has acted as a competent and very demanding user on a very big scale. Through long-term contracts radically new and advanced products have been developed. In the Scandinavian countries there is a growing debate on the possibilities of building 'welfare–industrial complexes' oriented towards the fulfillment of social needs in relation to energy, housing, environment, transport and the health service. Such complexes might, if the public sector acts as a competent user with a long-term perspective, be as effective as 'warfare–industrial complexes' in provoking new technology. There is no reason to believe that the positive impact upon the well-being of citizens should be less.

Social innovation as the basis for technical innovation

In a period characterized by radical change in the technological basis of the economy, established organizational and institutional patterns might prove to be important obstacles to the exploitation of the full potential of new technology. In such a period, social innovations might become more important for the wealth of nations than technical innovations. The Gorbachev drive for social change and democratization in Soviet Union might be seen in this light. In the capitalist countries the focus is still narrowly oriented, either towards the manipulation of financial variables or towards an 'acceleration of technological progress'. Institutional change, strengthening the competence and the power of final users, might be one of the social innovations which can give national systems of innovation a stronger position in the world economy. It would also imply that unsatisfactory innovations became less frequent.

The need for social innovations and institutional change is even more urgent at the world level. The enormous and growing gaps between rich and poor countries reflect that the international transmission of knowledge and technology is not working as assumed by standard economy theory. In so far as specific technological capabilities are rooted in national networks of user–producer relationships, 'technology transfer' can only solve part of the problem, however. There is a need for strengthening the whole national system of innovation, including science, industry and final users.

Notes

1. The basic ideas presented in this chapter have many different and heterogeneous sources. They reflect a collective effort among the IKE group, at Aalborg University, where a research team, studying Industrial Development and International Competitiveness, has pursued theoretical and empirical work, based upon a dual inspiration from French industrial economics and British innovation theory. An earlier, but more extensive, presentation of those ideas and their different sources can be found in Lundvall (1985). This booklet was worked out in 1984, during my stay as a visiting fellow at the Science

Policy Research Unit, Sussex University, and at the Department of Economics, Stanford University, and financed by a grant from the Social Research Council in Denmark. Christopher Freeman, Carlota Perez, Luc Soete, Keith Pavitt, Kenneth Arrow, Nathan Rosenberg, Paul David and many others at SPRU and in Stanford commented generously upon my work. This version has benefited not only from discussions with the participants at the Lewes and Maastricht meetings but also from comments from my colleagues and friends in Aalborg, Esben Sloth Andersen, Bjørn Johnson, Asger Brændgaard, Bent Dalum, Birgitte Gregersen and Lars Gelsing.

2. Adam Smith recognized the significance of this separation, presenting it as an important source of wealth and productivity growth: 'All the improvements in machinery, however, have by no means been the inventions of those who had occasion to use the machines. Many improvements have been made by the ingenuity of the makers of the machines, when to make them became the business of a peculiar trade' (Smith, 1776, p. 8).
3. We believe, however, that the user–producer perspective might be useful in clarifying how the different stages in the chain of innovation relate to each other in different parts of the economy.
4. It is interesting to note that Williamson, in his most recent work, recognizes that most transactions take place in organized markets. The dichotomy between pure markets and pure hierarchies is substituted by a scale where those two forms represent the extreme points. It is now argued that most transactions take place 'in the middle range' of such a scale (Williamson, 1985, p. 83). But still his analysis tends largely, to neglect the process of innovation *per se* as a factor reinforcing vertical integration and organized markets. Recent contributions by Japanese economists (Imai and Itami, 1984) do take into account technical innovation as a factor affecting the pattern of organized markets, but their focus is primarily management strategies rather than the implications for economic theory.

References

Amann, R. and Cooper, J. (eds) (1982), *Industrial Innovation in the Soviet Union*, New Hawen, Conn., Yale University Press.

Andersen, E.S., Dalum, B. and Villumsen, G. (1981), 'The importance of the home market for the technological development and the export specialization of manufacturing industry', in *Technical Innovation and National Economic Performance*, IKE seminar, Aalborg, Aalborg University Press.

Arrow, K.J. (1974), *The limits of organization*, New York, W.W. Norton & Company.

Bandt, J. de (1985), 'French industrial policies: successes and failures', in *A Competitive Future for Europe?*, congress report, Rotterdam.

Bandt, J. de and Humbert, M. (1985), 'La mésodynamique industrielle', in *Cahiers du CERNEA*, Nanterre.

Brændgaard, A., Gregersen, B., Lundvall, B.-Å., Maarbjerg-Olesen, N. and Aaen, I (1984), *Besparelser eller beskæftigelse: en undersogelse af danske kommuners anvendelse af EDB og ETB*, Aalborg, Aalborg University Press, 1984.

Carter, A.P. (1986), 'Diffusion from an input–output perspective', paper presented at the Conference on Innovation Diffusion, Venice, March 1986.

Chesnais, F. (1986), 'Some notes on technological cumulativeness: the appropriation of technology and technological progressiveness in concentrated market structures', paper presented at the Conference on Innovation Diffusion, Venice, March 1986.

Dalum, B. and Fagerberg, J. (1986), 'Diffusion of technology, economic growth and intra-industry trade: the case of the Nordic Countries', paper presented at the Second Knoellinger Seminar, Aabo, April 1986, mimeo.

David, P. (1984), 'On the perilous economics of modern science', paper presented at the TIP Workshop, Stanford University, August 1984, mimeo.

Dosi, G. (1982), 'Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change', *Research Policy*, vol. 11, no. 3, 1982.

Freeman, C. (1982), *The Economics of Industrial Innovation*, London, Frances Pinter.

Freeman, C. and Perez, C. (1986), 'The diffusion of technological innovations and changes of techno-economic paradigm', paper presented at the Conference on Innovation Diffusion, Venice, March 1986.

Georgescu-Roegen, N. (1971), *The Entropy Law and the Economic Process*, Cambridge, Mass., Harvard University Press, 1971.

Gregersen, B. (1984), *Det miljøindustrielle kompleks: teknologispredning og Beskæftigelse*, Aalborg, Aalborg University Press.

GRESI (Groupe de réflexions pour les stratégies industrielles) (1975), *La Division Internationale de travail*, Paris.

Hippel, E. von (1976), 'The dominant role of users in the scientific instruments innovation process', *Research Policy*, no. 5.

Kornai, J. (1971), *Anti-equilibrium*, Amsterdam, North-Holland.

Lundvall, B.-Å. (1985), *Product Innovation and User–Producer Interaction*, Aalborg, Aalborg University Press.

Lundvall, B.-Å., Maarbjerg-Olesen, N. and Aaen, I. (1983), *Det lanbrugsindustrielle kompleks: teknologiudvikling, konkurrenceevne og beskæftigelse*, Aalborg, Aalborg University Press.

Mowery, D. and Rosenberg, N. (1979), 'The influence of market demand upon innovation: a critical review of some recent empirical studies', *Research Policy*, no. 8, pp. 102–153.

Nelson, R.R. (1962), 'The link between science and invention: the case of the transistor', in National Bureau of Economic Research, *The Rate and Direction of Inventive Activity*, Princeton University Press.

Nelson, R.R. (1986), 'The generation and utilization of technology: a cross-industry analysis', paper presented at the Conference on Innovation Diffusion, Venice, March 1986.

OECD, (1983), 'Report on the results of the workshop on research, technology and regional policy', DSTI/SPR/83.117.

——, (1986), 'Technical cooperation agreements between firms: some initial data and analysis', DSTI/SPR/86.20, May.

Pasinetti, L. (1981), *Structural Change and Economic Growth*, Cambridge, Cambridge University Press, 1981.

Pavitt, K. (1984), 'Sectoral patterns of technical change: towards a taxonomy and a theory', *Research Policy*, vol. 13.

Rosenberg, N. (1976), *Perspectives on Technology*, Cambridge, Cambridge University Press.

—— (1982), *Inside the Black Box: Technology and Economics*, Cambridge, Cambridge University Press.

Rosenberg, N. and Mowery, D. (1978), 'The influence of market demand upon innovation: a critical review of some recent empirical studies', *Research Policy*, no. 8.

Rothwell, R. and Gardiner, P. (1985), 'Invention, innovation, re-innovation and the role of the user: a case study of British Hovercraft development', *Technovation*, no. 3.

Scherer, F.M. (1982), 'Inter-industry technology flows in the United States', *Research Policy*, no. 4, 1982.

Smith, A. (1776), *An Inquiry into the Nature and Causes of the Wealth of Nations*, Dent edn. (1910).

Williamson, O.E. (1975), *Markets and Hierarchies: Analysis and Antitrust Implications*, New York, Free Press.

—— (1985), *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting*, New York, Praeger.

Yakushiji, T. (1986), 'Technological emulation and industrial development', paper presented to the Conference on Innovation Diffusion, Venice, March.