# 2. Patterns of innovation and the determinants of the diffusion process in selected EU member states

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## 1. INTRODUCTION

Technological change is the result of both research and imitation activities. As soon as the information about the advantages provided by the innovation becomes available to the potential adopter, the adoption will take place.

Adoption is the result of a complex process of decision making. Absorption is just the process of diffusion perceived from the perspective of the recipient of the technique. The adoption of a new technology is in fact part of a broader process of technological change. Diffusion, defined as a sequence of adoption lags, is fully explained by the characteristics of the spreading of the information. Much attention has been paid to the identification of the determinants of the diffusion of the demand side and the determinants of the supply side.

Diffusion can be analysed as the process of delayed adoptions and imitations of a given innovation, with fixed economic characteristics, including the performances and the price, occurring because of dynamics on the demand side. The main engine is a well-known epidemic contagion in a population of heterogeneous agents, characterized by information asymmetries, and the eventual decay of information costs for potential adopters, driven by the dissemination of information carried out by all those who have already adopted (Griliches, 1957).

This chapter examines the diffusion process and reviews its patterns and determinants. In addition, it examines and reviews the main models and also investigates the correlation between adoption, innovation activities, the diffusion process and the growth process.

## 2. ADOPTION AND THE DIFFUSION PROCESS

The distinction between innovation and imitation was first introduced by Joseph Schumpeter (1934) and eventually became a landmark in the economics of innovation and new technology.

A new technology, either a new product or a new process, is first introduced by an innovator and eventually imitated by competitors. Imitators copy the innovation and in so doing enter the market and reduce the excess profits of the innovator. Imitation restores perfect competition. The economics of diffusion addresses relevant questions about the characteristics and the determinants, and the effects of the diffusion process. What is most controversial is why imitation is not instantaneous and all firms do not adopt it at the same time (Stoneman, 1976, 1983, 1986, 2002).

Adoption and innovation are two complementary aspects of a broader process of reaction to the mismatch between expectations and facts, and eventual introduction of technological changes that build upon the creative adoption and recombination of internal and external technological knowledge. The identification of the role of adoption costs paves the way for the distinction between gross and net profitability of adoption. Adoption costs are defined by the broad range of activities necessary to identify an innovation and adapt it to the existing production process. Adoption costs include the costs of search and adaptive research, the costs of scrapping the existing fixed production factors, the restructuring of the production and marketing organizations, the re-skilling of personnel, the actual purchase of the capital good and intermediary input embodying the new knowledge, the purchase of patents and licences and the costs of technical assistance (Amendola and Perrucci, 1985, 1986).

Net profitability of adoption is the result of the algebraic sum of the gross profitability engendered by the adoption of an innovation and the costs that it is necessary to incur in order to identify, select and finally adapt the new technology to the existing production conditions (Antonelli, 1990).

Figure 2.1 illustrates that the positive and constant slope of adoption costs is associated with the number of adopters and the positive, but decreasing, slope of the gross profitability of adoption is also associated with the number of adopters, the net profitability. The rate of diffusion will be influenced by the adoption costs and gross profitability of adoption, and also by the dynamics of technological change (Korres, 2011).

The distinction between diffusion within final consumers and diffusion within firms makes it possible to stress the related distinction between gross and net profitability of adoption and the identification of its costs. The distinction between net and gross profitability together with an

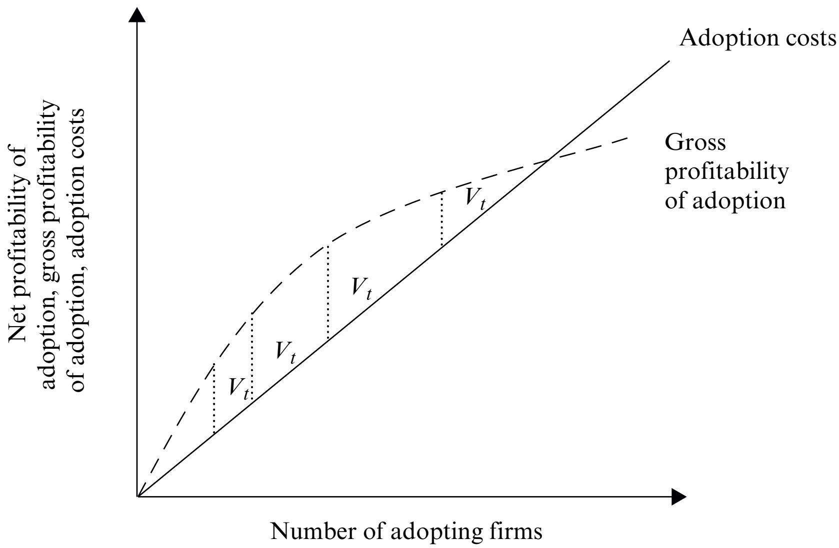



*Figure 2.1 Adoption costs, gross net profitability of adoption and diffusion process*

understanding of their dynamics, including the effects of the stocks of adoption on the evolution of the net profitability of adoption, provides an analytical probe that combines the demand and supply tradition of analysis of diffusion and shows the complementarity between innovation and adoption within the context of the economics of technological change (Korres, 2011).

## 3. THE DETERMINANTS AND THE PATTERNS OF DIFFUSION MODELS

The literature on diffusion of technology incorporates the best-known 'inter-industry innovation approach' pioneered by Mansfield (1961, 1988). This approach attempts to study diffusion as one or more innovations in a number of industries, and tries to explain empirically the variance of the speed of diffusion in terms of differences in the attributes of the industries and innovations concerned. Box 2.1 illustrates the main determinants of the demand and supply sides of innovation diffusion.

According to Schumpeter (1934), the diffusion process of major innovations is the driving force behind the trade cycle (the long-term Kondratieff cycle). However, the forces driving the diffusion process *per se* are not

## BOX 2.1 DETERMINANTS OF INNOVATION DIFFUSION

**Demand side:**

- Investment in human capital (increases ability to adopt innovations)
- Investment in R&D (increases ability to adopt innovations)
- The level of prior related knowledge owned by the firm adopting the innovation
- The balance between specialization and diversity in order to absorb external knowledge
- Organizational innovation, ability of users to make organizational changes, kind of organizational structure
- The size of the firms
- Market characteristics of potential users; share of the market; market dynamism; demand growth; number of previous adopters in the market

**Supply side:**

- R&D and innovation capacity of new-technology suppliers
- The financial means (advertising costs, users' guide etc.)
- Interaction between users and suppliers
- Exchanges of tangible and intangible assets, i.e. trade, FDI, face-to-face contacts, labour mobility etc.
- ICT facilitates awareness about the new technology
- Market structure: horizontal integration favours flows of tangible and intangible assets
- Geographical concentration facilitates awareness of the new technology
- Role played by the standardization procedures
- Insurance system
- IPRs (intellectual property rights)
- Competition
- Integration of the economies

*Source:* Suriñach et al. (2009).

made explicit. The idea is that the entrepreneur innovates and the attractiveness of attaining a similarly increased profit and similar cost reduction encourages others to imitate; this imitation represents a diffusion process.

The Schumpeterian approach investigated and tried to explain long waves in economic activity (the Kondratieff cycle). The Schumpeterian hypothesis is concerned with the implications of new technology on the economy. In Schumpeterian theory, the entrepreneur introduces innovations and the resulting profits give the signal for imitation by other entrepreneurs. The introduction of new technologies results in the reduction of factor and product prices. The change of prices will induce non-adopters to use the new technology (Korres et al., 2003).

Diffusion of technology can be defined as the process by which the use of an innovation spreads and grows. Diffusion is very important for the process of technological change. On the one hand, it narrows the technological gap between the economic units of an industry, and thus the rate of diffusion determines to a large extent the rate of technological change measured as the effect of an innovation on productivity increase in an industry. On the other hand, diffusion plays an important part in the competitiveness process in the sense that it blunts the competitive edge maintained by the originator of successful innovations. Schumpeter has classified technological change in the following steps (Korres, 2011):

(a) invention;
(b) innovation; and
(c) diffusion.

Diffusion is the last step in the economic impact of a new product or process. It is the stage in which a new product or process comes into widespread use. Figure 2.2 illustrates the importance of diffusion in the process of technological change (Chen, 1983; Korres, 2011). Most literature on diffusion is focused on the theoretical arguments underlying the traditional S-shaped epidemic diffusion curve (Korres, 2011).

## 4. REVIEW OF THEORY AND EVIDENCE

### 4.1 The Epidemic Model and the Logistic Curve

Many diffusion models (e.g. Davies, 1979; Stoneman, 1987) are based on the approach of the theory of epidemics. Epidemic models can be used to explain how innovation spreads from one unit to others, at what speed and what can stop it. The epidemic approach starts with the assumption that

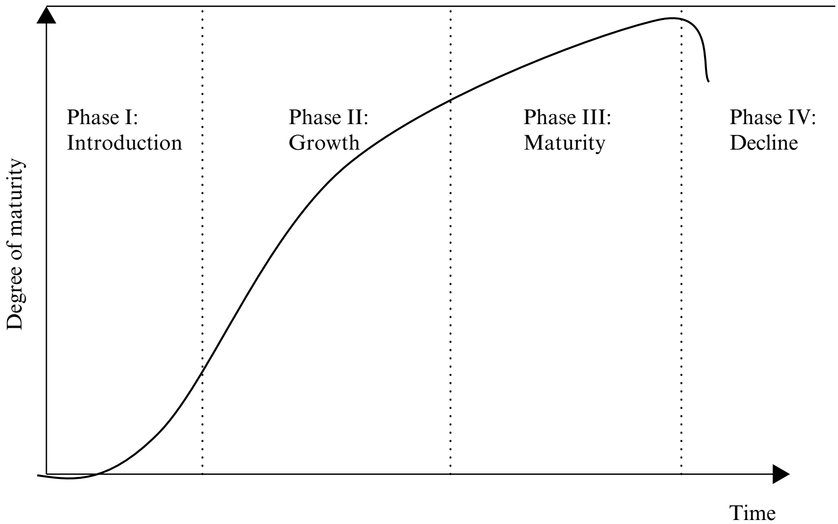
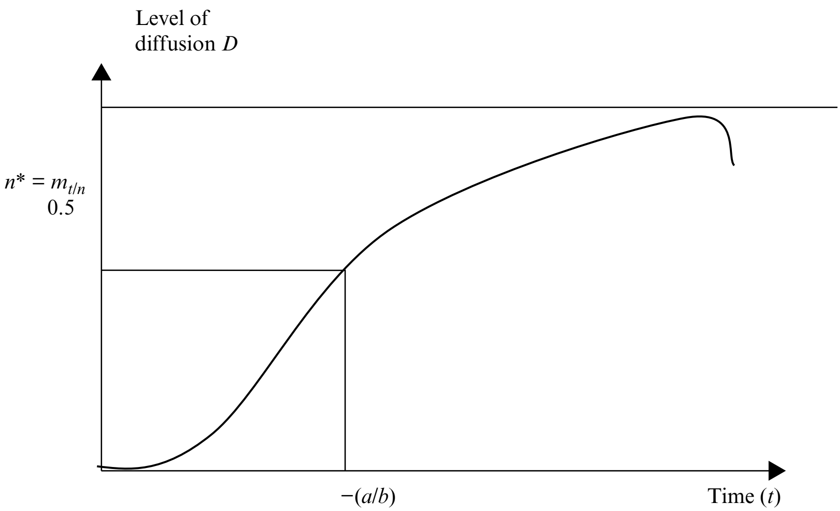



*Figure 2.2 The S-shaped curve: the diffusion and growth process*

the diffusion process is similar to the spread of a disease among a given population. The basic epidemic model is based on three assumptions:

- the potential number of adopters may not be in each case the whole population under consideration;
- the way in which information is spread may not be uniform and homogeneous;
- the probability of optimizing innovation once informed is not independent of economic considerations, such as profitability and market perspectives.

The epidemic model is based on the idea that the spread of information about a new technology is the key to explaining diffusion. Epidemic models hypothesize that some firms adopt later than others because they do not have sufficient information about the new technology. According to this theory, potential adopters initially have little or no information about the new technology and are therefore unable or disinclined to adopt it. However, as diffusion proceeds, non-adopters glean technical information from adopters via day-to-day interactions, just as one may contract a disease by casual contact with an infected person. As a result, as the number of adopters grows, the dissemination of information accelerates, and the speed of diffusion increases.




*Notes:* (*a*/*b*) = spread of new technology; *D* = level of diffusion; *n* = total firms in a population; $m_t$ = number of adopters in a population; $n-m_t$ = number of potential adopters in a population.

*Figure 2.3 The logistic epidemic curve*

The spread of new technology among a fixed number of identical firms can be represented as follows. Let us assume that the level of diffusion is *D*, which corresponds to $m_t$ number of firms in a fixed population of *n* which have adopted the new innovation at time *t* and to $(n-m_t)$ firms that remain as the potential adopters. Figure 2.3 illustrates the logistic epidemic curve. There is a huge literature on the law of logistic growth, which must be measured in appropriate units. Different studies on plants and animals were found to follow the logistic law, even though these two variables cannot be subject to the same distribution. Population theory relies on logistic extrapolations. The only trouble with this theory is that not only the logistic distribution but also the normal, the Cauchy, and other distributions can be fitted to the same material with the same or better goodness of fit. Examining the logistic curve, we can summarize the following disadvantages:

- the infectiousness of the disease must remain constant over time for all individuals; this means that *b* must be constant; however, in the case of a reduction in the contagiousness of the disease, *b* falls over time;
- all individuals must have an equal chance of catching the disease.

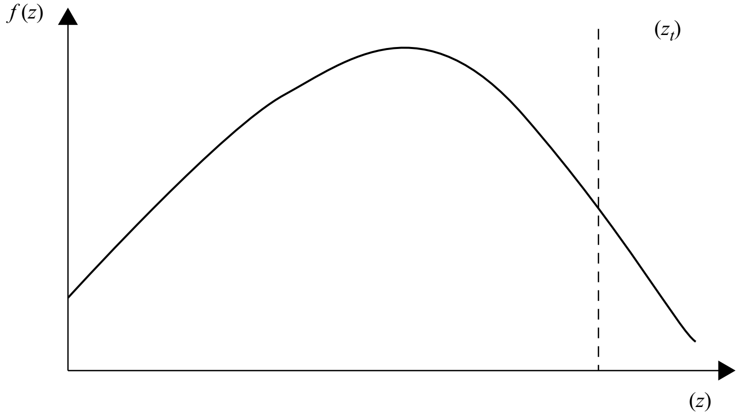
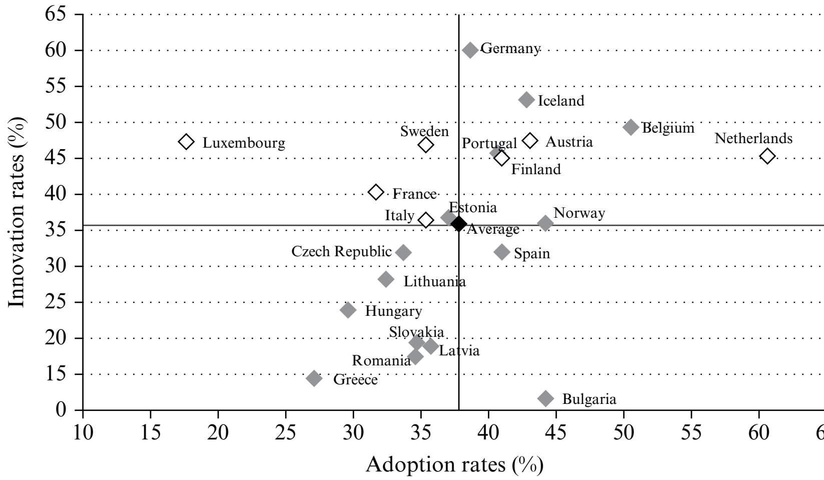



*Figure 2.4* *The cumulative distribution*

## 4.2 The Probit Models

Probit analysis is a well-established technique in the study of diffusion of new products between individuals. This approach concentrates on the characteristics of individuals in a sector and is suitable not only to generate a diffusion curve, but also to give some indication of which firms will be early adopters and which late. Given the difficulties associated with the linear probability model, it is natural to transform the original model in such a way that predictions will lie between the (0,1) interval for all $X$. These requirements suggest the use of a cumulative probability function ($F$) in order to be able to explain a dichotomous dependent variable (the range of the cumulative probability function is the (0,1) interval, since all probabilities lie between 0 and 1).

The probit probability model is associated with the cumulative normal probability function. The central assumption underlying the probit model is that an individual consumer (or a firm/country) will be found to own the new product (or to adopt the new innovation) at a particular time when the income (or the size) exceeds some critical level. Let us assume that the potential adopters of technology differ according to some specified characteristic, $z$, that is distributed across the population as $f(z)$ with a cumulative distribution $F(z)$, as Figure 2.4 illustrates. The advantage of the probit diffusion models is that they relate to the possibility of introducing behavioural assumptions concerning the individual firm (firms). The probit model also offers interesting insights into the slowness of the technological diffusion process.




*Note:* The average adoption rate given in the figure (and in the following figures) is computed as an average of the country rates and not as a global rate computed from the country and industry database.

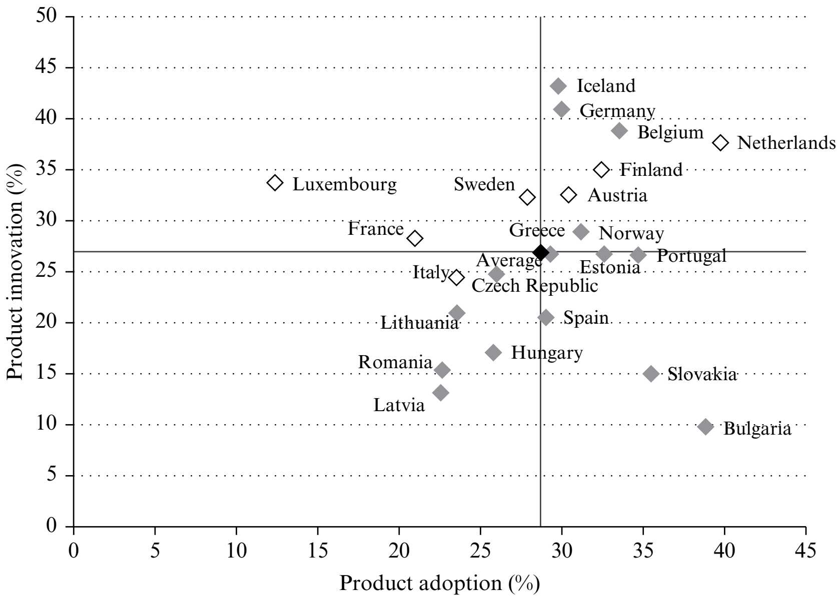
*Source:* Suriñach et al. (2009).

*Figure 2.5 Innovation and adoption rates by selected member states*

Furthermore, a number of economists (such as Mansfield, 1961; Sahal, 1977) consider diffusion as a disequilibrium phenomenon. Usually, when a new technology or a new method is introduced, it is less developed than the older method with which it competes. Therefore it is likely to have greater potential for improvement and for reduction in cost. The introduction of a new product or process broadens the range of choice of producers and consumers, and the equilibrium is altered. In the real world, there is only a gradual adjustment over the course of time to the new equilibrium level.

## 4.3 Diffusion and Adoption Process: Evidence from European Member States

The performance of innovation adoption for European member states seems to be more important for process innovations than for product innovations. Cooperation activities drive innovation adoption at the EU level while the acquisition of innovations from external innovators is a less important source of adoption of innovation (both process and product). Figures 2.5–2.7 illustrate the innovation and adoption rates by



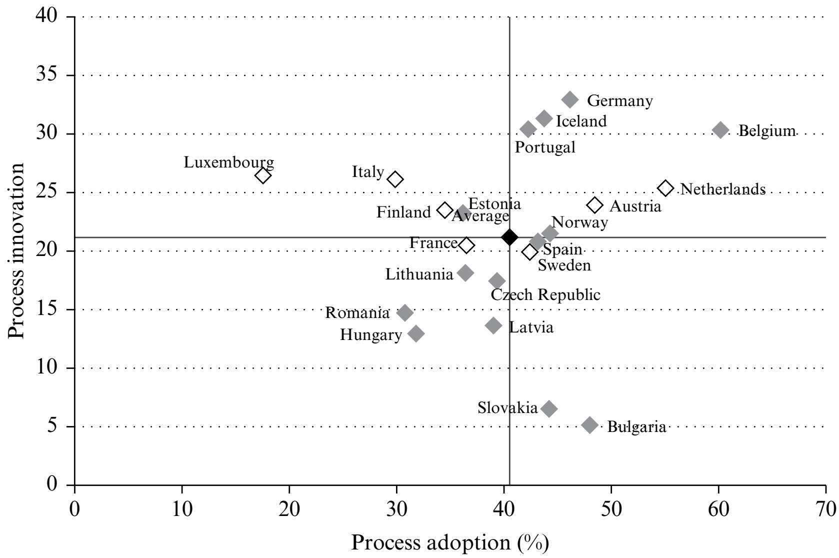

*Source:* Suriñach et al. (2009).

*Figure 2.6 Product innovation and product adoption by member states*

member states, product innovation and the product adoption by member states, and process innovation and process adoption by member states, respectively.

The most important features of the diffusion process of innovation activities are, according to Suriñach et al. (2009):

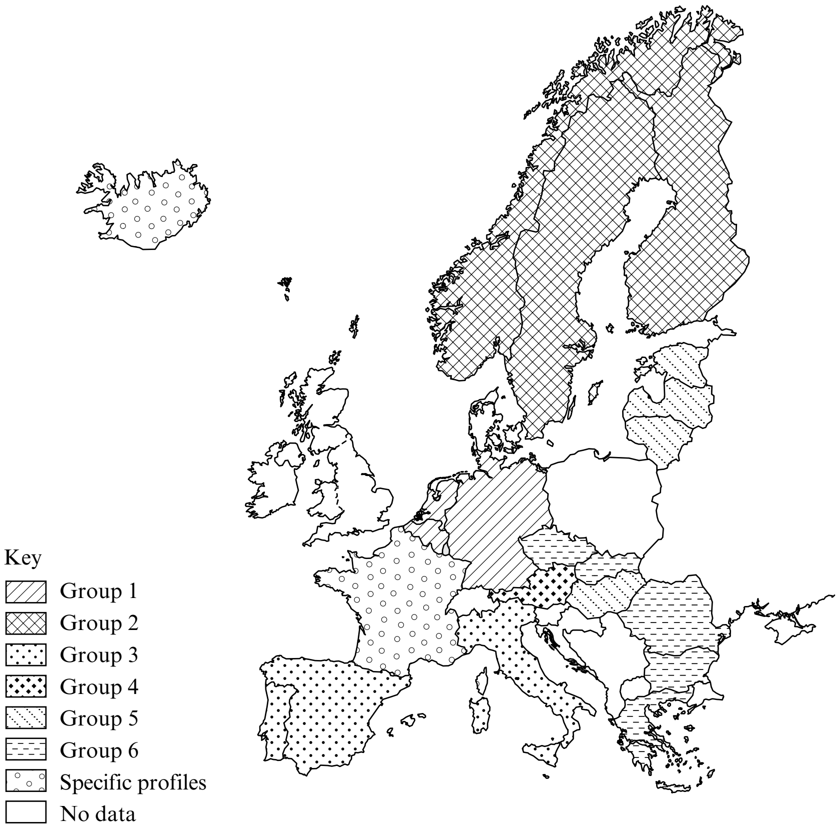
- For all European states, the adoption rate is higher in the case of process innovation (41 per cent) than product innovation (28 per cent). So, innovation adoption is more process oriented (even if innovation on its own is more product-oriented, 24 per cent of EU firms make process innovations versus 28 per cent that perform product innovations).
- Innovation adoption rates vary substantially across EU member states. The highly innovative countries seem also to be those that are more engaged in adoption activities. Luxembourg has a high rate of innovation but the adoption rate is very low. This feature can also be observed for France and Sweden but to a lesser extent. Bulgaria has a very low innovation rate but an important adoption rate.




*Source:* Suriñach et al. (2009).

*Figure 2.7 Process innovation and process adoption by selected member states*

- The average percentage of adoptive firms is equal to 39 per cent; this rate varies a great deal according to countries. The maximum value is observed for the Netherlands with 61 per cent, then for Belgium with 51 per cent. On the contrary, the minimum value is observed for Luxembourg with 18 per cent. This percentage is low if compared to other countries since all other values are between 27 per cent and 44 per cent.
- The member states with low innovation rate also record a low adoption rate. This applies to Greece and to the majority of Eastern Europe countries (Romania, Latvia, Slovakia and Hungary). On the contrary, countries with high innovation rates have higher adoption rates (such as Belgium, the Netherlands, Iceland, Germany and Austria).
- European member states with higher rates of product innovation also experience higher rates of product adoption (apart from the specific cases of Bulgaria and Luxembourg). The same is true for process innovation activities; those countries innovating more on process are also those that seem to benefit from process innovation adoption.

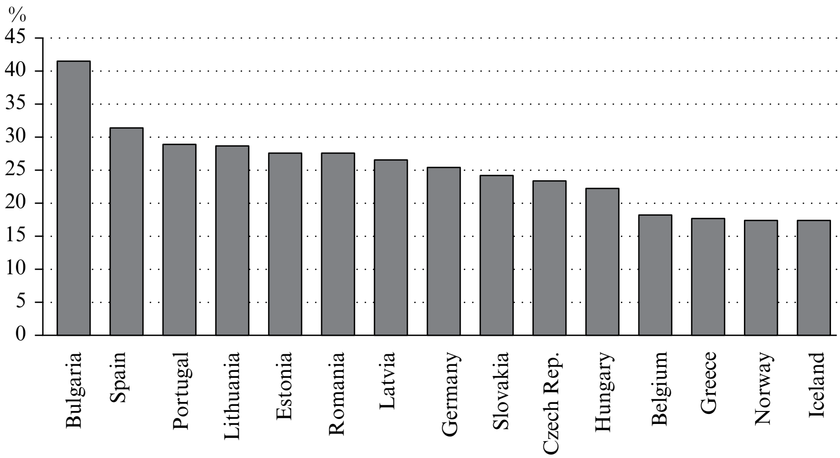



*Source:* Suriñach et al. (2009).

*Figure 2.8 Geographical pattern of EU states according to their adoption and innovation levels*

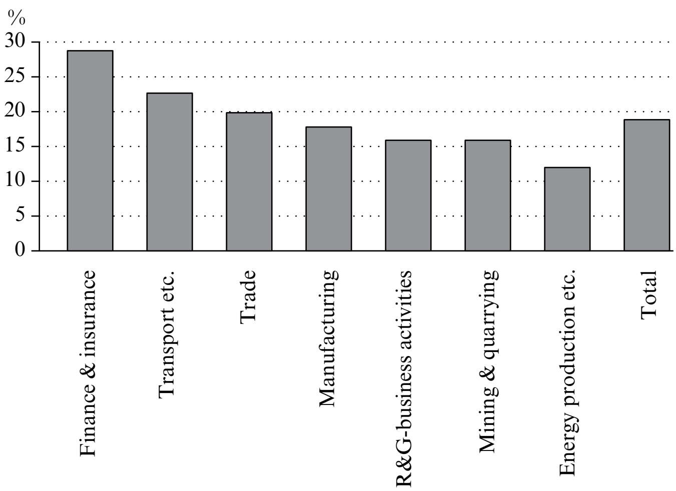
Figure 2.8 illustrates the geographical pattern of EU states according to their adoption and innovation levels. According to these results, groups 1 and 2 face high adoption rates while, on the contrary, groups 5 and 6, which differ in their innovative and general economic features, register low adoption rates.

Figures 2.9–2.11 illustrate the share of sales due to adoption, the share of both product and process adopting firms by sector and also the innovation adoption rates in the EU, respectively. Regarding the adoption behaviour in the sectoral case, we can state the following facts (Suriñachi et al. 2009):



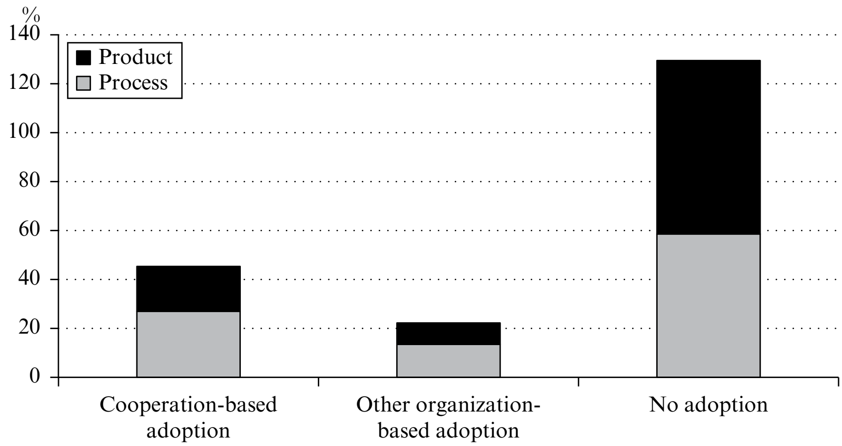

*Source:* Eurostat.

*Figure 2.9 Share of sales due to adoption (based on 'new to the firm' definition of adoption)*




*Source:* Eurostat.

*Figure 2.10 Share of both product and process adopting firms over total adopting firms by sector*




*Source:* Eurostat.

*Figure 2.11 Innovation adoption rates in the EU*

- For both product and process innovations, cooperation rates are particularly high for wholesale trade, financial activities and transport and communication (and energy only for process innovation adoption). On the contrary, manufacturing and extractive industry record the lowest rates.
- Whatever the sector and the nature of innovation (product or process), cooperation is more frequent than outsourcing to other organizations.
- The adoption is more cooperation-based for process innovation than product innovation, whatever the sector.

## 5. SUMMARY

New technologies imply some micro effects (on firms and organizations) and some macro effects (on industrial sectors) for the whole economy. In addition, new technologies play an important role in the productivity and competitiveness of a country. For instance, the faster the technological progress, the faster should the factor productivity rise and the less should 'cost-push' exert upward pressure on the price level. The principal effects for technological policy can be distinguished on the demand and supply sides.

Diffusion is the spread of a technology through a society or industry.

The diffusion of a technology generally follows an S-shaped curve as early versions of technology are rather unsuccessful, followed by a period of successful innovation with high levels of adoption, and finally a dropping off in adoption as a technology reaches its maximum potential in a market.

Most of the empirical literature focuses on the impact of innovation diffusion on economic growth. In addition, most of the literature analyses the determinants of innovation adoption, both micro and macro level. Also, countries with a higher level of innovative activities seem to be also those more dynamic in the context of innovation adoption. It is clear that fostering innovation activities may also be associated to some extent with spillover effects (which can take place through 'adoption mechanisms') leading to higher levels of diffusion and adoption of innovation.

For any innovation, the costs of entry for the innovator can be represented as the sum of the following components: the fixed investment cost in plant and equipment; the cost incurred by the innovator in acquiring scientific and technical knowledge not possessed by the firm at the beginning of innovation process; the cost incurred by the innovator in acquiring the relevant experience (know-how in organization, management, marketing or other areas) required to carry the innovation through; and the cost borne by the innovator to compensate for whatever relevant externalities are not provided by the environment in which the firm operates. Imitators will compare the cost of buying the technology with the cost of developing it themselves, if they can. However, the imitators' knowledge related to the entry costs will depend crucially on their own initial scientific and technical knowledge base in the relevant areas. Consequently, the entry costs may be much higher or much lower than the innovators, depending on their relative starting positions in the knowledge level of the firm. Furthermore, government regulations, taxes, tariffs and other relevant policies will strongly affect environmental and actual costs for an innovator. Specifically, the difficulty of catching up for industries/firms in the developing countries exists because scientific and technical knowledge, practical experience and locational advantages may be lower than in the more advanced countries, while those of technology may be higher.

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