ANNEX II.1
Theories of economic growth

Neo–classical growth models

Early neo-classical growth models emphasised the role of capital accumulation. In the Solow–Swan model[14], output is produced by capital and labour. Economic growth is compatible with labour-augmenting technical progress, which acts as if it were increasing the available amount of labour. In the long-term, output per capita and labour productivity grow at an exogenously given rate of technical progress. Technical progress is entirely exogenous to these models so that in reality economic growth is left unexplained.

The canonical model provides a methodology (growth accounting) for measuring the rate of technical progress, the so-called Solow residual or total factor productivity (TFP) growth[15]. TFP is defined as the difference between output growth and the (share-weighted) growth rates of capital and labour inputs. Because of its nature as a residual, it is in fact a "measure of our ignorance". Clearly, many factors can cause a shift in the production function, such as technical innovation or organisational and institutional change. The difficulties with this methodology are revealed by the contradictory estimates: while in Solow's pioneering study, growth in per capita income was almost entirely (88 per cent) attributed to TFP growth, subsequent more careful measurement of factor inputs led to inputs explaining virtually all of output growth, thus reducing the residual to zero[16].

Empirical studies in the 1990s, based on the neo-classical tradition, set out to reconcile the Solow–Swan model with, among other issues, international empirical evidence on convergence. Mankiw et al. (1992) augmented the aggregate production function with human capital proxied by educational attainment. They found that the Solow model performs well in explaining cross-country differences in income levels and is even more successful when human capital is taken into account, and concluded that the model is consistent with the international evidence, if one acknowledges the importance of human, as well as physical, capital. A major drawback of this work are the assumptions that the level of productivity and the rate of technical change are the same across nations; these are not empirically verifiable assumptions.

Endogenous economic growth and the role of ideas

A group of models that emerged in the course of the 1980s explain long-term economic growth endogenously, by relaxing the assumption of diminishing returns to capital and by rendering technological progress endogenous to the model. Output and productivity growth do not rely on exogenous technical progress.

In a pioneering paper, Romer (1986) postulated that R&D activities are associated with externalities which affect the stock of knowledge available to all firms. A firm's production function is defined by firm–specific variables (capital services, labour and R&D inputs) and a shift term (index of technology) which is a function of the stock of knowledge available to all firms; this reflects the public-good characteristics of knowledge–generating activities such as R&D. Clearly, it is possible to view the shift term as reflecting a "learning

14 See Solow (1956) and Swan (1956).
15 Growth accounting continues to be used, especially today in the area of measuring the contribution of ICT to economic growth; see Stiroh (2001).
16 See Jorgenson and Griliches (1967).

by doing" process, or the influence of the stock of human capital[17]. It is evident that the endogenous growth theory has the potential to take into account a variety of factors enabling innovation.

R&D– or ideas–based endogenous growth models identify and explicitly model innovation (in particular, the accumulation and diffusion of technological knowledge) as the driving force of long-term economic growth. In these models, "ideas" (in the form of blueprints for new products or new processes) are generated by investment in R&D. Thus, these models treat R&D as an entrepreneurial activity performed by profit-maximising firms. "Ideas" generated by R&D lead to new processes and products that are used as inputs in the production of final goods. As input goods of superior quality, or as more specialised intermediate or capital goods, these products raise productivity[18]. It is now widely recognised that while R&D–based innovation is a crucial determinant of the competitiveness of firms, it does not exclusively affect the performance of those actually undertaking these activities but gives rise to important external effects ("R&D spillovers"). An important element of these external effects is "knowledge spillovers", which take place if new knowledge generated by the R&D activities of one agent stimulates the development of new knowledge by others, or enhances their technological capabilities.

The commercial outcome of “ideas” – new processes and products – is very often characterised by very high fixed costs and low marginal costs. It can be very costly to produce the first copy of a computer programme, whereas reproducing it can subsequently be done at virtually zero cost. This implies that the economics of ideas is typically associated with increasing returns and imperfect competition.

Economic theory also suggests that the international diffusion of knowledge increases the growth of output and productivity. Eaton and Kortum (1996) find that more than 50 per cent of the productivity growth in each of the 19 OECD countries included in their sample can be attributed to innovations from just three countries (US, Germany and Japan). These three countries, together with France and the United Kingdom, reap more than 10 per cent of their growth from domestic research.

The impact of international technology diffusion on productivity growth takes place through three channels. First, access to a larger pool of knowledge increases the productivity of R&D activities in the countries involved, thereby enhancing future productivity growth. As a consequence, a country's productivity growth is positively correlated with the degree of its openness to flows of information and to its capability to absorb and utilise knowledge generated abroad. In this process, domestic R&D may be instrumental in building and maintaining absorptive capacities. Second, international trade provides opportunities to use the input goods developed abroad that differ qualitatively from domestic input goods, and thus to increase productivity. And, third, both international trade and foreign direct investment are vehicles for cross–border learning about products, production processes, market conditions, etc. and may lead to a reduction in the costs of innovating and contribute to increases in TFP.

Evolutionary models of economic growth

The evolutionary approach to growth draws attention to three aspects that are neglected in both neo-classical and endogenous growth models. First, technological advancement ought to be conceptualised as a disequilibrium process involving high ex–ante uncertainty, path dependency and long–lasting adjustment processes. Secondly, growth theory should be based on a more realistic theory of the firm that stresses (strategic) firm capabilities in a broad sense, rather than just investment in human capital and R&D. Thirdly, it must take into account the institutional framework that presumably contributes strongly to an explanation of cross–country differences in economic growth[19].

It is clear that, in this approach, measures to enhance firm capabilities and the development and strengthening of institutions conducive to growth become core areas of policy. The relevance of the evolutionary approach is reflected in policy discussions and design in many countries, as well as implicitly in the European Union and in the work of the OECD.

Dynamic firm capabilities

The standard approach to explaining productivity (growth) at the firm level is a production function, a concept that is seen as particularly narrow. To create value and gain a competitive edge, a firm uses a whole bundle of specific assets, among which R&D is only one, though an important one. Others are mar-

17 See Lucas (1988).
18 See, for example, Romer (1990).
19 See Nelson (1998).

keting, organisational and managerial skills, individual and collective learning capabilities, social capital (trust, etc.), networking (customer links, outsourcing, co-operation with universities, strategic alliances, etc.), property rights (patents, brand names), etc. This bundle of firm–specific, mostly intangible assets are considered to be the firm's capabilities. They are dynamic in nature, being the result of strategic decisions in the past, and represent the resources to create additional assets in the future. Strategic asset accumulation enables a firm to change restrictions with respect to technology and taste. It is obvious that this accumulation process is path–dependent and gives rise to important differences among firms[20].

As capabilities are difficult to measure at the aggregate level, it may also be difficult to use this approach to explain aggregate economic growth. Nevertheless, empirical work in Peneder (2001) yields a strongly positive cross–country correlation between various capability indicators and performance measures such as productivity, unit values and wages. The (aggregate) capability approach, which appears to be useful for comparing and explaining economic performance among countries, is adopted in the empirical analysis of manufacturing growth in Chapter IV of the present Report.

National Innovation Systems the role of interconnected institutions

The evolutionary approach recognises that institutions are crucial in explaining the performance of firms and of the economy as a whole. The institutional framework is shaped to a large extent at the national level, giving rise to important differences across countries. However, the internationalisation and diffusion of knowledge can be a mitigating factor in this regard. This aspect of growth theory belongs to the "National Innovation Systems" (NIS) approach, which can be seen as the macroeconomic counterpart of the capability view of the firm.

NIS is a set of interconnected institutions (firms, universities, governments, etc.) which jointly determine a country's performance in the generation and diffusion of technologies and the development of skills[21]. This approach is based on the hypothesis that the performance of a (national) economy in terms of innovation and productivity is not only the result of public and private investments in tangibles and intangibles, but is also strongly influenced by the character and intensity of the interactions between the elements of the system. As a consequence, country differences with respect to innovation and growth might reflect not just different endowments with innovation–related factors of production but also varying degrees of the "knowledge distribution power" or, more generally, the efficiency of NIS.

However appealing, this approach encounters severe data problems in empirical work. Important properties like the "quality of public policy", incentive mechanisms in firms and in "non–market" institutions etc. are difficult to approximate empirically with confidence. In view of this, it is not surprising that there is no overall measure of the efficiency of a NIS which could be used as an explanatory variable in the empirical analysis of economic growth. What is available at present are only pieces of evidence showing the importance of several types of interaction for innovation performance; for a summary of this evidence see, for example, OECD (1999)[22]. Nevertheless, because the evolutionary approach yields insights into the dynamics of growth processes at the conceptual level, its basic ideas provide a useful framework for policy design and analysis. Consequently, it is now the dominant paradigm for innovation policy and a core element in policy–oriented growth analysis, and plays a crucial role in defining best policy practices in these fields. In Chapter IV, a set of indicators based on suggestions from the evolutionary model are used to explain empirically cross-country differences with respect to economic growth.

While the evolutionary theory shares the basic policy conclusions of the endogenous growth theory, the former also sees the need for some specific measures. By stressing the ex-ante uncertainty of technical change, it implies that it would be necessary to have a mechanism to guarantee technological variety at an early stage of technological development in order to avoid large-scale investment failures. Therefore, creating a favourable environment for entrepreneurship and new ventures is an important policy task (lowering start-up costs, fostering the provision of venture capital, etc.), while the selection of superior technologies is left for the market to determine. The capability view of the firm implies that measures facilitating investment in intangibles are important. While in principle such investments are up to private business to undertake, there might be at the same time scope for a policy, for example, to make sure that incentives for training are put right (measures against poaching, tax incentives, etc.).

20 See Foss (1997).
21 See, for example, Freeman (1987) and Nelson (1993).
22 See also Stern et al. (2000) and the material from the OECD Growth Project in OECD (2001).

The NIS framework also supports the need for specific policies. Here, measures aimed at improving the interaction between the various elements of the system (strengthening science-industry relationships and joint research, facilitating university spin-offs, exchange of highly qualified staff, facilitating R&D co-operation in the private sector) ought to be encouraged. Policy makers should also take into consideration the specificity of the policy context. In particular, the best policies have to be adapted to the specific properties and needs of the NIS.

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