Evidence on R&D Impact Using Macroeconomic and General Equilibrium Models

Executive summary

One of the key elements of the Lisbon strategy is the target of raising R&D spending to 3% of GDP by 2010 for the Union. This is quite understandable given the central role of R&D investments in driving productivity growth and fostering competitiveness in a global world where knowledge and innovation are critical factors for the advanced economies.

The effectiveness of R&D in each Member State depends on the industrial structure and on the innovative capacities of enterprises. Socio-economic differences and attitudes towards innovation and risk taking also play a role (career choices, university-industry relationships, etc.)

Investigating the relations between industrial R&D efforts and economic performance in the Member States in terms of competitiveness, growth and employment is a difficult and complex task. Empirical evidence on the links between knowledge input and economic output can be incorporated in different types of multi-country models in order to better assess the impact of input and parameter changes on R&D and the impact of increases in R&D on economic growth and employment.

Currently available econometric models are not particularly well suited to address such questions as they lack some of the crucial linkages for the study of the effects of R&D. They are also too aggregate and in most cases lack the appropriate sectoral disaggregation. The theoretically more appropriate models mostly do not have the necessary country coverage and detail on sectors of the economy, and many of them lack the necessary macroeconomic linkages. Therefore a combination of the results of simulations on the best available models is needed to investigate the contributions of R&D to economic growth and employment.

For this purpose, three models are used in this study:

- **QUEST**, the macroeconometric model developed by the Econometric Modelling Unit of DG ECFIN;
- **GreenMod**, a dynamic multi-sector and multi-country general equilibrium model developed by a team at the Free University of Brussels and EcoMod Network;
- **E3ME**, a multi-sector and multi-country model for analysing the long-term implications of Energy-Environment-Economy (E3) policies, especially those concerning R&D and environmental taxation and regulation. The E3ME model has been built by an international team including Cambridge Econometrics.

These three state-of-the-art models have strong capabilities to address the possible impacts of increased R&D investment on the EU economies:

- All three models are capable of providing dynamic simulation results over at least a 15-year period.

- All three models cover all 25 Member States, and include specific country models for most of them.
- GreenMod and E3ME have a detailed sectoral disaggregation and distinguish all the major, labour and capital markets.

QUEST was designed to analyse the economies in the member states of the European Union and their interactions with the rest of the world, especially with the United States and Japan. The focus of the model is on the transmission of the effects of economic policy both on the domestic and the international economy. The model was primarily constructed to serve as a tool for policy simulation; less emphasis was put on its ability to serve as a forecasting tool. Given the wide coverage of the model it must necessarily be highly aggregated. A high degree of aggregation and foundation of the specification in current macroeconomic theory also helps in interpreting and understanding the results of the simulations. The new version contains structural models for the EU member states, the US and Japan and distinguishes 10 additional countries/regions in trade feedback models in order to model trade interactions with the rest of the world.

In the new version of QUEST an attempt was made to base the behavioural equations more strongly on principles of dynamic optimisation of private households and firms. That makes the model substantially more forward looking. Also the supply side is now more explicitly modelled. Moreover, financial linkages between national economies are now more explicitly modelled. The long run properties of the model are also systematically explored.

GreenMod is a recursively dynamic, multi-sector, multi-country, multi-regional computable general equilibrium (CGE) modelling platform. For countries for which data is available, the GreenMod has the capability of distinguishing different regions within countries and different types of households. However, for the purpose of this project we only use the model disaggregation at the country level and nation-wide representative household.

The model incorporates the economic behaviour of four economic agents in each region/country: firms, households, government and the rest of the world. All economic agents are assumed to adopt an optimizing behaviour under relevant budget constraints. The country/region, household, sector, and commodity disaggregation is fully flexible and is adjusted to the policy issues the simulations are run for. Given the very large size of the model, the simulations are not run with specifically aggregated levels for both the geographic and sectoral dimensions.

For the simulations required by this project, all the Member States are included in GreenMod. The database has been aggregated to the following sectoral details:

1. Agriculture
2. Energy and transport
3. Low-tech manufacturing
4. Medium-tech manufacturing
5. High-tech manufacturing
6. R&D
7. Other Services

The simulation horizon of the model is set at 25 years but can be extended in a flexible way. The model is solved dynamically with annual steps. The model has a recursive dynamic structure composed of a sequence of temporary equilibria, in which current savings determine future capital accumulation and the growth rate of the economy. Two types of capital are distinguished in each period: a "malleable" part and a "rigid" part, whereas the possibilities of substitution among factors of production are assumed to be higher for the malleable than for the rigid capital (vintage capital). Thus, the technology is assumed to have a putty/semi-putty specification.

GreenMod has powerful capabilities for impact and scenario analysis, as well as for medium and long term projects at the sectoral, country, and regional levels takings into account dynamics interactions between markets and agents. Policy simulations with GreenMod provide detailed results on a large number of macro and sectoral variables regarding the impacts of shocks.

E3ME is designed to meet the need for a framework for analysing the long-term implications of Energy-Environment-Economy (E3) policies, especially those concerning R&D and environmental taxation and regulation. The model is also capable of addressing the short-term and medium-term economic effects as well as, more broadly, the long-term effects of such policies, such as those from the supply side of the labour market.

E3ME combines the features of an annual short- and medium-term sectoral model estimated by formal econometric methods with the detail and some of the methods of the Computable General Equilibrium (CGE) models that provide analysis of the movement of the long-term outcomes for key E3 indicators in response to policy changes. It can be used for dynamic policy simulation and for forecasting and projecting over the medium and long terms.

The detailed nature of the E3ME model allows the representation of fairly complex scenarios, especially those that are differentiated according to sector and to country. Similarly, the impact of any policy measure can be represented in a detailed way.

The econometric grounding of the model makes it better able to represent and forecast performance in the short to medium run. It therefore provides information that is closer to the time horizon of many policy makers.

Using several models to analyse the impacts of increased R&D spending is both an innovative approach and a very challenging task. The three models used in this study encompass the main state-of-the-art modelling techniques for impact assessment, scenario analysis and projections. The theoretical structures, the construction techniques, and the type of data these models use are very different. All three models are moreover high-dimensional tools. It is extremely difficult and demanding in terms of human resources, computational time, and data to establish bridges between them.

In order to provide the most reliable results, our team has done extensive data work, collected all the available recent input-output, sectoral, R&D, and macro data. The models have been updated using the most recent available data.

The three models are calibrated on a common baseline provided by the QUEST projections of DG ECFIN as much as possible and a given trajectory of R&D expenditure so that the impact

of policy changes to achieve a given R&D target can be compared. The calibration is based on a comparison of the effects of input and parameter changes on a number of key variables, including GDP growth and employment.

The model simulations provide the likely impacts of targeted R&D increases on GDP growth, employment, unemployment, sectoral production, trade, prices, public finance, etc in different Member States and the EU25.

Two policy scenarios are considered:

1. R&D investment targets in the national reform targets and
2. R&D investment targets in the Lisbon strategy.

The model simulations provide the likely impacts of targeted R&D increases on GDP growth, employment, unemployment, sectoral production, etc in different Member States and the EU25.

Even if there are some major differences between countries, model simulations show significant and positive impacts on growth in all the EU member states. Simulation results show that the growth impacts in the new member states are much higher in both the national programme and Lisbon scenarios. The impact on real GDP in some countries such as Cyprus, Estonia, Latvia, Lithuania, Malta, Poland, and Slovakia is even larger than 30 percent. Growth effects are also large in some older member states such as Greece, Spain and Portugal given that they start from a lower R&D base.

R&D causes an increase in productivity in all EU25 countries. There are, however, major differences between the scale of the effects across individual countries and sectors. R&D spending is likely to be more effective in sectors where innovation tends to be a result of research spending rather than gross investment.

E3ME and GreenMod results show that the impacts on the various industries would be quite different. Output would increase significantly in a number of sectors, especially in the manufacturing sectors, high R&D intensive sectors expanding even faster.

The countries with the largest responses to increases in R&D spending are Ireland and Germany in the EU15 and Slovakia in the EU10. In most cases the largest increases in output, which feeds directly into the labour productivity calculation, come through exports (Germany is an exception, where consumer spending increases). It is, therefore, not surprising that the largest increases in productivity tend to come from countries and sectors that are heavily export-oriented. The largest increases in productivity tend to come in manufacturing sectors. This is not surprising given that they are less labour-intensive and are in a better position to benefit from more efficient production methods.

The initial effect of increased R&D spending is to reduce imports. However, this is outweighed by the effects of the overall increase in demand so that, in most cases, imports increase. In particular, imports of raw materials are needed by the R&D-intensive sectors to produce their (usually manufactured) goods.

This means that if the full benefits of higher R&D spending are to be realised, it must be supported by a trade policy that allows R&D-intensive sectors both to export their goods, and to import the material components of their production processes.

E3ME simulations results also show that the effects on employment are different in the EU15 and the EU10. In the EU15, a 10% increase in R&D spending results in a 0.8% long-term increase in employment. The corresponding figure for the EU10 is just 0.3%. In the QUEST results, the employment effects are very small for most of the new member states with the exception of Poland, even negative for several of them such as Cyprus, Estonia, Latvia, Lithuania, and Malta. GreenMod simulations provide significant positive effects on the labour market in all the new member states. The differences in the labour market outcomes stem from the differences in the modelling of the labour market in the three models.

As the main effect of R&D is to increase exports, R&D spending in one country can have a large impact on output in another. Overall this effect is positive and again there are sectoral variations, with the largest increases in output likely to be in industries that supply raw materials to the R&D-intensive sectors. While the country that does not increase R&D will see a loss of competitiveness in its R&D-intensive sectors, this is less than the increases due to higher demand in export markets. In summary, trade is not a zero-sum game.

The growth effects provided by the GreenMod simulations are lower than QUEST's. This may be due to the fact that the GreenMod results do not capture the spillover effects through the foreign trade channel. GreenMod results might therefore underestimate the growth effects in the new member states. The second difference in the simulation set-up is that QUEST recycles the additional tax revenues through a reduction in the social security contributions.

In addition to model simulations, this report also provides an extensive literature review and data analysis, and the methodology on the link between TFP growth and R&D investments.

Our data analysis show that the pharmaceuticals, electronics, motor vehicles and other transport equipment sectors are ranked amongst the most important investors in R&D activity. Interesting, the sectors with the highest R&D intensity also turned out to be the most volatile during the 1995-2002 period. Aside from this quartet of industries, the following others are also worthy of attention: mechanical engineering, electrical engineering/instruments and chemicals. The rationale behind their inclusion lies also in the relative importance and volatility of their roles as R&D investors. In one or two instances, certain service industries such as computing and professional services have exhibited a high level of volatility in their R&D shares overtime.

What are the impacts of R&D investments on productivity? Our econometric analysis and the extensive literature review show that there is a great deal of variability in the estimation results. Nearly all studies surveyed conclude that R&D does matter for productivity growth. In spite of the large variance in the measured elasticities and returns, we can summarize the results as follows:

- At firm level, the elasticities tend to lie around the 10%-30% range whereas the rates of returns concentrate in the 20%-30% range.

- At industry level, the elasticities turn around the 8%-30% range whereas the rates of returns are mostly in the 20%-40% range.

As far as dynamics is concerned, it appears that the elasticity has first decreased, to reach a minimum in the early 80s and that it re-increased again in the subsequent periods. Several studies show that the elasticity of TFP with respect to business R&D has been growing over time since the early 80s, which confirms the impression that R&D is an increasingly important activity for firms in the knowledge-based economy. However, the elasticity with respect to public R&D has decreased over the same period.

At the theoretical level, governmental R&D investment policies may be hindered by three factors:

- Crowding out of private spending by public spending
- Displacement of private funding (the government finances investments that would have occurred anyway)
- Inefficient resource allocation by the government

Econometric estimates of interaction between public and private R&D investments show that both fiscal incentives and direct funding stimulate business-funded R&D, whereas research performed by the government appears to have a crowding out effect and the research performed by the higher education sector has no impact.

R&D activities generate many externalities: other firms, industries, or countries may benefit from research activities performed in a particular place. Rent and knowledge spillovers may arise across industries within a given country, across countries within a given industry, and across countries and industries.

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