Economic effects of stimulating business R&D

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Executive summary

The innovative strength of a nation's business sector is one of the key factors of that nation's ability to compete in the international dimension. Among other relevant input factors, private investments in R&D are extremely important for boosting that innovative strength. Due to the positive externalities (spillover effects) of business R&D the social returns to these investments are higher than the private returns achieved by the firms making the actual investments in R&D (R&D investors). A consequence of this imperfection in the knowledge market is that firms tend to invest less in R&D than is optimal from the social point of view. Because of this, the government stimulates business R&D, among other things by financial incentives.

The main question dealt with in this paper is: what are the economic effects of these financial government incentives? The answer is of particular importance with a view to the question whether the government should intensify, or conversely, cut down on its R&D incentives policy. The economic effects of these R&D incentives are determined by a multitude of factors; factors which also tend to interact. In addition to the spillover effects referred to above, the main decisive factors are: the extent to which the government incentives really do lead to an increase in business R&D, and the direct effects of this extra R&D on business performance. A total of 12 mechanisms are distinguished, all of which have an effect on the economic effects of R&D incentives. These twelve mechanisms are placed in a total framework in this paper.

An increasing amount of (national and international) empirical studies on the separate *partial* mechanisms has been published in recent years. These results are set out and used in this paper to underpin the crucial coefficients of an applied general equilibrium model called MESEMET-2. This empirically-based model is then used to calculate the macroeconomic effects of an increase in government R&D incentives.

A simulation carried out with MESEMET-2 shows that an increase in the government's stimulation of business R&D leads to a considerable increase in gross value added of enterprises. According to the model calculations, a government incentives increase of 0.1% of the gross value added in enterprises leads to an approximate 1.0% extra gross value added in enterprises in due course. In other words: *one* extra guilder in government incentives will result in about *ten* guilders extra gross value added in enterprises in due course. On balance, the beneficial economic effects of R&D incentives also result in an improvement of the budget balance of the government.

The positive economic effects of R&D incentives do not so much depend on the actual size of the multiplier (the relationship between extra business R&D and the government's incentives), but are determined mainly by the highly beneficial effects of the extra R&D on sales and the gross value added in enterprises. This is influenced significantly by a positive effect of R&D on the total factor productivity. A direct effect on export demand is also important: a greater foreign demand for innovative and high-quality products. The direct effect on demand leads to a higher export price. In return, a terms of trade gain is achieved by enterprises, and this has a positive effect on profitability and fixed capital formation by enterprises.

The impact on employment is relatively limited. This is resulting from the assumption that in the longer term the labour market will clear completely due to wage adjustments (a strong Phillips curve effect). This, in the current tight labour market situation, is in every way a defensible assumption to make. The increase in economic growth due to the extra business R&D is, in our analysis, not so much the result of a greater input of production factors, but is chiefly due to an increase in productivity.

All in all, this paper shows that the economic effects of the government's stimulation of business R&D are particularly beneficial. The paper also sets out the mechanisms that lead to this result, and which mechanisms are of particular importance in this respect.

1. Introduction

Investments by enterprises in R&D are very important for today's knowledge-intensive economy. R&D efforts contribute to the level of and utilisation of knowledge, which in turn is crucial for the ability of enterprises to innovate products and production methods. This ability to innovate is the key factor in international competition. Innovations are necessary to achieve cost-efficiency, but also highly important in order to maintain the required quality and originality of products. That investments in R&D are useful and profitable has been demonstrated in economic research frequently. The R&D efforts of enterprises have both direct and indirect economic effects. The R&D carried out in any firm contributes to the performance of that firm itself, but due to spillovers from that R&D also to the performance of other firms.

Although R&D expenditure in the Dutch business sector has increased over the past few years, this R&D expenditure is fairly low in the Netherlands compared with other OECD countries. This is one of the weak points of the Dutch economy at a time when knowledge and innovative capacity are becoming increasingly more important for the international competitive position of firms and for generating economic growth.

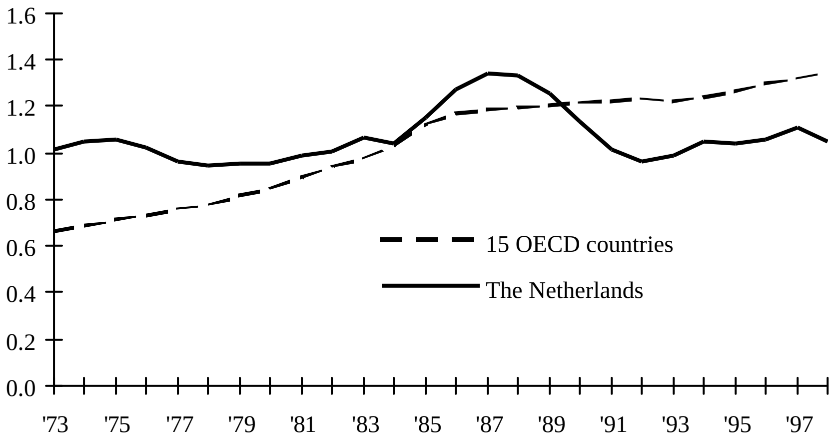
The government can stimulate business R&D, among other things, with financial incentives. The existence of positive externalities from business R&D justifies this government support to business R&D. Due to spillovers R&D efforts of firms contribute far more to the economy than the private returns for the firms that carry out that R&D. The social returns to business R&D are therefore higher than the private returns. A consequence of this imperfection in the knowledge market is that firms tend to invest less in R&D than is optimal from the social point of view. If left entirely to the market, firms will allocate less resources to R&D than the socially optimal level. It would therefore seem unwise, on economic theoretical grounds, to accept the relatively low R&D expenditure by enterprises in the Netherlands.

The goal of this paper is to gain an insight into the economic effects of financial government incentives for business R&D. These economic effects are determined by a multitude of factors; factors which also tend to interact. In addition to the externalities already mentioned, the main decisive factors are: the extent to which government incentives really do lead to an increase in business R&D, and the direct effect of this extra R&D on business performance. Many empirical studies have been done on the various sub-aspects in recent years. In this paper we make an initial attempt to place the available empirical knowledge within a total framework. Then, by means of model simulations, we set out a picture of the macroeconomic effects of R&D incentives. However, first of all we will take a brief look at the amount of business R&D carried out in the Netherlands in comparison with other countries, and compare the amount of financial government support to business R&D in a number of countries.

2. Business R&D in the Netherlands in comparison with other countries

An international comparison of R&D expenditure is usually made on the basis of R&D intensity. This is an indicator which expresses R&D expenditure as a percentage of the gross domestic product (GDP). In terms of R&D intensity, R&D expenditure in Dutch enterprises has been lower than the average of 15 OECD countries since the beginning of the nineties, while in the two decades prior to that, Dutch R&D intensity was (far) above the average (Figure 1).[1]

Figure 1 R&D intensity enterprises (% GDP), the Netherlands and the average of 15 OECD countries, 1973-1998



Source: Nieuwenhuijsen (1999), updated on the basis of OECD (2000a) and recent CBS figures.

The 15 countries were chosen on the basis of data availability for the study conducted by Nieuwenhuijsen (1999) into the stock of R&D capital. See Table 1 for a list of these countries.

It may thus be noted that the Netherlands only achieves a moderate score in the field of business R&D expenditure. This is also apparent from Table 1 in which 15 OECD countries are arranged in order of their R&D intensity. The Netherlands comes in the

[1] The OECD average presented in Figure 1 is a non-weighted average of the 15 OECD countries. For the period after 1981 a weighted average is also available for the total OECD area in which the R&D intensity in the different countries is weighted on the basis of the total GDP (see CBS, 1999, p. 210; OECD, 2000a, p. 26). This weighted OECD average is even considerably higher (in 1998: 1.54) because countries such as the United States and Germany with a relatively high R&D intensity carry more weight.

ninth position. This is certainly a poor score for a nation that has the ambition of being a knowledge economy, and by virtue of this fact alone *should* be in a relatively high position.

Table 1 R&D intensity[1] enterprises in 15 OECD countries; 1998 or most recent other year

Country	R&D intensity (%)	Standardised R&D intensity[2] (%)
Sweden (1997)	2.77	1.44
Japan	2.18	0.85
United States	2.04	0.71
Finland	1.95	0.62
Germany	1.55	0.22
France	1.35	0.02
United Kingdom	1.21	-0.12
Denmark	1.20	-0.13
The Netherlands	1.05	-0.28
Ireland (1997)	1.03	-0.30
Canada	1.01	-0.32
Norway (1997)	0.95	-0.38
Australia (1997)	0.71	-0.62
Italy	0.55	-0.78
Spain	0.47	-0.86

[1] R&D intensity = R&D expenditure as a percentage of the gross domestic product

[2] Standardised R&D intensity = R&D intensity deviating from the average of the 15 OECD countries (1.33%)

Source: Nieuwenhuijsen (1999), updated on the basis of OECD (2000a) and recent CBS figures.

The mediocre position of the Netherlands can be explained partly by the sectoral structure of the Dutch economy. According to research carried out by Hollanders and Verspagen (1998, 1999), the Netherlands continues to score low even if R&D intensities are adjusted for differences in sectoral structure. Moreover, the Netherlands scored much better in the seventies and eighties with a similar sectoral structure. Other explanations, such as the relatively substantial public R&D in the Netherlands, and the low defence-related R&D expenditure, do not alter the fact that private expenditure on R&D is too low.

R&D expenditure can be regarded as investments in the stock of R&D capital. Might the Netherlands perhaps achieve a better score if we look at the accumulated investments in R&D? It appears from a recent study conducted by Nieuwenhuijsen (1999) that a similarly disappointing score is obtained for the Netherlands if the stock of R&D capital is compared internationally. At a private R&D capital intensity (stock of R&D capital in % of GDP) of 6.34% in 1995, the Netherlands is still in the ninth place among the 15 OECD countries. The average of the 15 OECD countries is 7.05%, whereby countries such as Germany, France, the US, Japan and Sweden are way above the 10% mark. The knowledge built up in the Netherlands in the seventies and eighties by investing relatively large amounts in R&D has meanwhile become obsolete and has consequently been written off. Dutch enterprises will need to invest above the average amount for several years in order to catch up in terms of R&D capital.

The picture for the Netherlands is not an unfavourable one for all parts of the knowledge economy.[2] The Netherlands has taken the lead in the EU as far as the percentage of the population belonging to the 'scientific and technological labour force' (Human Resources in Science and Technology) is concerned (CBS, 1999). The Netherlands also scores well regarding the total investment in intangible assets. These, in addition to private and public R&D expenditure, include expenditure on education, payments for foreign technology, marketing and software (CBS, 1999). Furthermore, investments in ICT are reasonably high in the Netherlands in comparison with other countries (OECD, 1999).

Nevertheless, output indicators indicate that the innovative strength of the Netherlands is on the low side. For instance: the share in turnover of new or improved products in Dutch industry, which stands at 25%, is considerably lower than the EU average of above 32% (Eurostat, 2000).[3] The growth rate of labour productivity in the Netherlands is also low compared with many other countries (OECD, 2000b). Another sign of a too low innovative strength is that the share of manufacturing value added realised in technology-driven sectors in the Netherlands is relatively low, in contrast with the share of marketing-driven and capital intensive sectors (European Commission, 1999). This confirms the analysis in the Dutch industrial policy letter 'Scope for Industrial Innovation' (Ministry of Economic Affairs, 1999) that the Netherlands has relied heavily on factor-driven growth, and will need to invest more in the near future in the development of an innovation-driven growth pattern.[4]

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2 As also indicated by Hollanders and Ter Weel (2000) and CBS (1999), p. 12.

3 Previous Eurostat figures pointed out a European average of 31% (Eurostat, 1999; CBS, 1999). According to more recent and more complete Eurostat figures (2000) the EU (excluding Luxembourg en Greece) averages 32,5%. These are figures for 1996.

4 This terminology is derived from Porter (1990). See also SER (2000), pp. 42-43 and 89-90.

This worrisome picture is confirmed in a study of Porter and Stern (1999). In a comparison of the innovative capacity of 17 OECD countries made by these authors, the Netherlands dropped from the eighth position in 1980 to the eleventh position in 1995. If policy remains unchanged, a further decrease is expected down to the thirteenth position by the end of 2005.

3. Government incentives for business R&D

The government stimulates R&D expenditure by enterprises in a variety of ways, among other things through a number of financial incentives. The main instruments today are the WBSO (Research and Development Allowances Act), the BTS (Subsidy Scheme for Industrial R&D Cooperation), the EET (Economy, Ecology and Technology R&D Programme) and the TOK (Technical Development Credit). Table 2 gives an insight into the amount of government support to business R&D by way of these financial instruments. A total sum in the region of NLG 750 million was provided in 1997 (excluding firms with fewer than 10 employees that were not included in the observations for CBS's R&D statistics). As a percentage of total business R&D expenditure, the government incentives over the past few years fluctuated around the 9%.

Table 2 R&D expenditure in the business sector and government support to business R&D[1,2]

Year	Business R&D expenditure (NLG million)	Government support to business R&D (NLG million)[3]	Share of government support in business R&D expenditure (%)
1970	1,336	58	4.3
1980	3,227	94	2.9
1990	5,808	615	10.6
1991	5,460	285	5.2
1992	5,393	239	4.4
1993	5,684	207	3.6
1994	6,422	573	8.9
1995	6,900	566	8.2
1996	7,364	684	9.3
1997	8,186	737	9.0

1 Financing by the European Union and the financing by (semi) public research institutes is not taken into consideration.

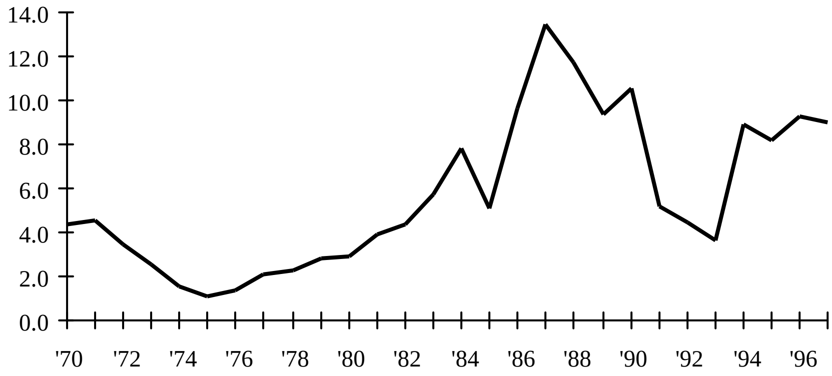
2 Figures are in accordance with the observation threshold of the CBS in the R&D statistics. Up to and including 1993 only firms with 50 or more employees, from 1994 also firms with 10-50 employees in manufacturing and mining and quarrying, and from 1996 also firms with 10-50 employees in the remaining sectors.

3 Subsidies, loans (gross, i.e. not adjusted for repayments), and as of 1994 the fiscal R&D facility WBSO. The WBSO figures are based on the 'realised' tax deductions according to data from the tax authorities (taking the CBS's observation thresholds in the R&D statistics into account).

Source: CBS (R&D statistics data) and Senter (WBSO data).

In Figure 2 we see that the relative amounts of government support fluctuated quite strongly in the past. The sharp increase in the second half of the eighties can be attributed to the subsidy scheme INSTIR (wage-cost subsidies for research personnel), that was introduced in 1984 and expanded in 1987. This scheme was discontinued in 1991 and thus the government's share in business R&D funding dropped considerably after that date. This share started to increase again in 1994, mainly because of the tax facility WBSO that was introduced in that year.

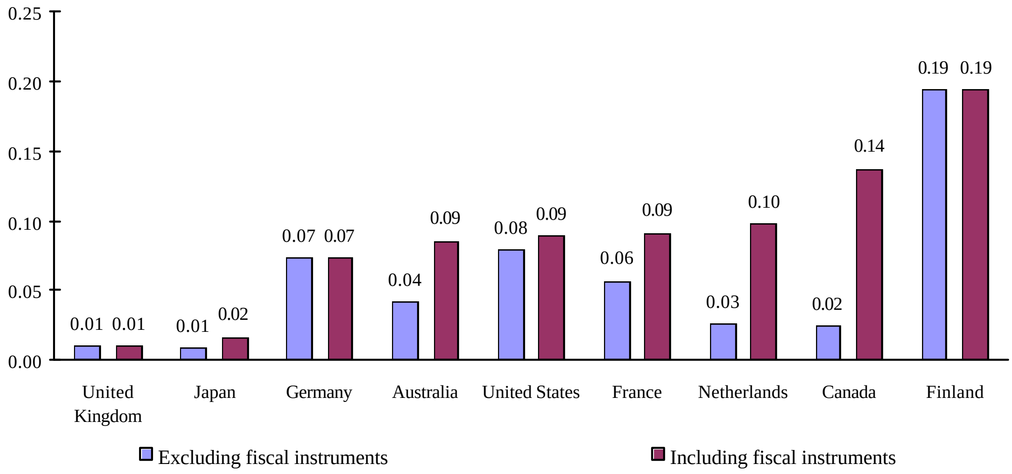
Figure 2 Share of government support in business R&D expenditure (%), 1970-1997



Source: CBS (R&D statistics data) and Senter (WBSO data).

Does the Netherlands, in comparison with other countries, spend relatively much or little on stimulating business R&D? The answer to this question depends to some extent on whether or not fiscal instruments are included. Using the most recent data, it is apparent that if fiscal instruments are *excluded*, then the Dutch Government spends relatively little on business R&D incentives (Figure 3). If the fiscal instruments *are* included, then we see that the Netherlands scores in the middle group with 0.10% of the GDP at a scale which is comparative with that of France, the United States and Australia.

Figure 3 Government support to business R&D in % of GDP, 1997 or most recent other year[1]



[1] Including fiscal instruments: 1995 for Canada and France. Excluding fiscal instruments: 1995 for Canada, France and Japan, 1996 for the United States and Australia.

Source: calculations based on OECD (1999), pp. 38-39 and 134.

Work is currently under way in many countries on intensifying government policy that aims to strengthen the knowledge intensity of the economy. This refers not only to promoting a linkage between the public and the private knowledge infrastructure, but also to making business R&D more financially attractive by way of grants and tax facilities.[5] Although the degree of financial incentives regarding business R&D from the government is one of the factors that determine the location of R&D-intensive firms [6], an intensification of the incentives policies in foreign countries does not warrant the same being done in the Netherlands. The consequences of such government policy must be judged on their own merits. In other words: whether the government should gradually withdraw its policy on stimulating business R&D, or whether it should continue it or intensify it, depends on the economic effects. In the following we therefore examine the economic effects of government R&D incentives.

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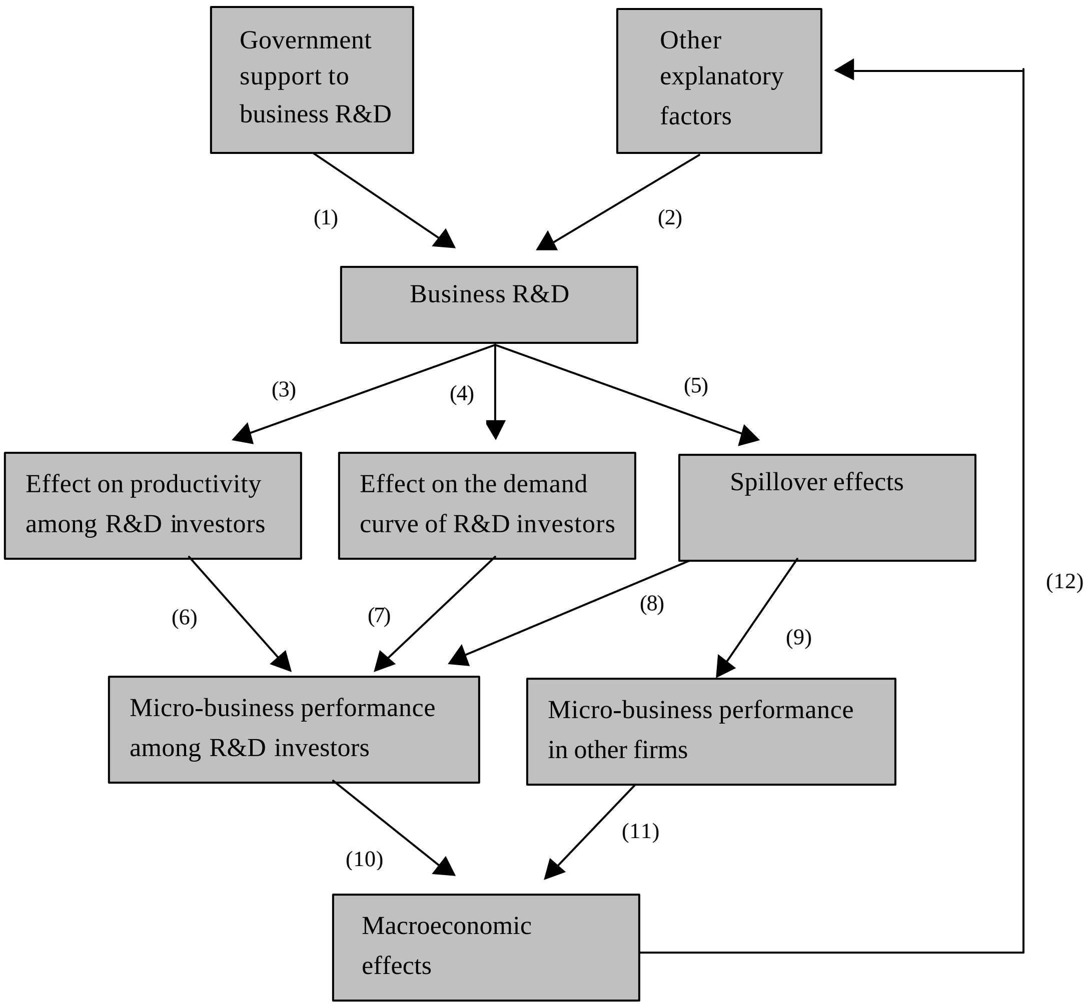
[5] Economic Policy Committee (2000).

[6] Minne (1997).

4. Schematic framework for the economic effects of stimulating business R&D

The relationship between government support to business R&D and the macroeconomic performance is complex and depends on several different factors. The diagram below has been used as a basis for providing insight into this complex relationship.

Figure 4 Government support, business R&D and economic effects



Let us first of all restrict ourselves to the mechanisms in force in the firms that actually make the investments in R&D, the R&D investors. Research shows that government support (1st arrow), in addition to a variety of other factors (2nd arrow), has an effect on the amount of business R&D.[7] However, this R&D is not the ultimate goal of government incentives, but only the means. The government's concern is the economic effects of the R&D. In this context we can distinguish two direct effects of R&D among R&D investors: a productivity effect (3rd arrow) and an effect on the demand curve (4th arrow).

R&D can lead to a higher level of productivity by bringing about an improvement in the production process and higher product quality. The higher level of productivity implies that a higher production volume can be achieved from a given input of labour and capital. Since this lowers the price of the products or the price-quality ratio, the result will be an increase in demand and consequently a higher actual production.

Product improvements and innovations can also lead to a direct increase in demand by way of an outward shift of the demand curve. In addition to a productivity effect we can therefore distinguish an effect on the demand curve. The background of this effect on the demand curve is twofold. Firstly, improvements in quality are difficult to measure and thus in practice they will not be expressed in full in productivity figures.[8] Consequently, the better market position firms are able to achieve due to this improvement in quality leads to an outward shift of the demand curve. Secondly, product innovations can take place without there being any question of improved quality. In that case, product innovations only contribute to a larger product variety. In itself, this product innovation can also increase the demand for products of a firm and thus lead to an outward shift of the demand curve.

By way of the productivity effect and the effect on the demand curve, investments in R&D influence the micro-business performance of R&D investors (6th and 7th arrows). This, among other things, relates to the effects on turnover, employment and the value added of a firm. Yet this is only part of the story. As already stated in the introduction, the positive externalities – by way of the spillovers – are the main driving force for the government to stimulate business R&D. It is the effects of R&D on firms other than those that actually invest in R&D that lead to the social return to these investments being higher than the private return. These spillover effects (5th arrow), which in turn can be broken down into productivity effects and effects on the demand curve, occur in the other firms that do, and those that do not invest in R&D. They consequently influence the micro-business performance of the R&D investors (8th arrow) and the micro-business performance of the other firms (9th arrow).

The effects of R&D on the micro-business performance of the R&D investors and the other firms determine together the macroeconomic effects on sales, value added,

7 For an overview of the empirical results found in the national and international literature, see Donselaar and Knoester (1999).

8 See, for instance, Griliches (1994) as well as the report of the American Boskin Commission: Advisory Commission To Study The Consumer Price Index (1996).

employment, investments, profitability, etc. (10th and 11th arrows). In this context, the continued macroeconomic effect of R&D on wages and prices, for instance, must also be taken into account, because of the feed back effects on business performance that are resulting from this. Finally, in addition to the first-order effects described above we also have second-order effects (12th arrow), because the changes in production and profitability, in turn, influence the amount of business R&D (2nd arrow).

An increasing flow of empirical material has become available on the separate parts of the process described above. The empirical results for these sub-aspects will be discussed below, after which we shall present an overall picture of the economic effects of R&D incentives on the basis of simulations using a macroeconomic model.

5. Effect of government incentives on R&D expenditure by enterprises

Donselaar and Knoester (1999) recently conducted a study into the determinants of R&D expenditure by enterprises in the Netherlands (1st and 2nd arrows in Figure 4). A regression analysis was used to determine which variables between 1972 and 1995 influenced the R&D intensity of enterprises. This study shows a positive influence on R&D expenditure by enterprises of government financing of business R&D, the profitability and solvency of enterprises, and the internationalisation of the economy. The real interest rate was found to have a negative effect. A distinction in government financing of business R&D was made between financing from the central government and financing from (semi) public research institutes. Funding originating from central government covers subsidies, loans and tax facilities for the purpose of stimulating business R&D. Funding originating from (semi) public research institutes relates to procurement of R&D, i.e. R&D assignments to enterprises, commissioned by (semi) public research institutes.

An adjustment was made in the empirical estimations for five large multinational firms, the so-called Big Five (Philips, Shell, Unilever, Akzo and DSM). These are the top five firms with the highest R&D expenditure in the Netherlands, which make up for a major part of the total R&D expenditure by enterprises in the Netherlands (in 1997 this was slightly above 40% after a downward trend from above 70% in 1970).[9] Estimates for the total business sector, i.e. including the five major multinationals, did not produce plausible results. The reason for this is that the R&D expenditure by the five large multinationals has dominated the development of total R&D expenditure by enterprises in the period 1972-1995, but cannot be explained accurately on the basis of macro-variables for the Netherlands. In particular some specific developments that took place in Philips (heavy investments in the megachip project between 1986 and 1988, and budget cuts related to the Centurion operation at the beginning of the 1990s) seem to distort the estimation results considerably. Confidential CBS data made it possible to make an adjustment for the Big Five firms, in turn making it possible to come up with a theoretically and empirically plausible explanation for the development of business R&D expenditures in the Netherlands.

The estimation results are shown in Table 3. The most explanatory variables are the extent of internationalisation and financial incentives from the central government. A significant multiplier of 1.04 (t-value 9.1) was found for the latter.[10] This means that, on average, every single guilder in government financing has led to more than one guilder in extra R&D in the business sector during the period investigated for the purpose of this study (1972-1995).

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[9] CBS (1999), p. 89.

[10] This multiplier of 1.04 was adjusted for repayments of TOK loans.

Table 3 Determinants of business R&D intensity[1]

	Coefficient	t-value (absolute)
internationalisation[2]	0.0045	10.1
financing from central government[3]	1.04	9.1
financing from (semi) public research institutes[3,4]	1.18	5.6
dummy for the years 1994 and 1995[5]	0.061	4.3
real interest rate	-0.009	3.7
solvency[6]	0.0065	2.7

1 The equation was estimated including the constant and explains 97% of the total variance of the explained variable. This variable is defined as follows: business R&D (of firms with 50 or more employees) excluding the Big Five firms, as a percentage of gross value added in enterprises.

2 The ratio between the volume of relevant world trade and the volume of gross value added in enterprises; index (1990 = 100).

3 Exclusive of the Big Five firms, as a percentage of gross value added in enterprises.

4 This relates to procurement of R&D, i.e. R&D assignments to firms, commissioned by (semi) public research institutes.

5 The dummy has been included because of the introduction of new methods of observation by the CBS in 1994, resulting in the detection of a higher number of firms engaged in R&D, particularly smaller firms in the service sector.

6 Share of equity capital in total capital (%).

Source: Donselaar and Knoester (1999).

A multiplier greater than zero implies that, on balance, due to government facilities additional R&D is carried out in the business sector. Regarded as such, the empirically-found multiplier of 1.04 can be deemed considerably high, certainly if it is taken into account that when providing these schemes it is impossible to prevent part of the government-provided funding from going towards R&D that would still have been carried out without them. Moreover, a pure interpretation of the result requires that it is taken into account that the government funds are subject to profit taxation. A part of the government financing therefore flows back into the treasury in the form of higher taxes on profit. If an adjustment is made to compensate for this, then the result is a ‘net’ multiplier of 1.8. The ‘gross’ multiplier of 1.04 corresponds with the values found earlier in the international literature, whereby it should be noted that the results presented in the literature vary considerably.

Although the R&D carried out in enterprises is not in itself a goal of government policy, it is important that we can observe that government financing really does lead to extra R&D in enterprises. Yet ultimately, it is the effect on the economy that counts. The main aspect is the extent to which government financing of business R&D contributes to the economic performance of enterprises. This will be looked at in the following chapters.

6. Direct effects of R&D on business performance

Van Leeuwen and Nieuwenhuijsen (1998a, 1998b) studied the direct effect of R&D on business performance for firms in Dutch manufacturing (3rd and 4th arrows in Figure 4). They used linked firm-level data from R&D statistics and Production Statistics (CBS) for the years 1985, 1989 and 1993. Van Leeuwen and Nieuwenhuijsen estimated a model in which the demand and productivity effect of business R&D is included. They applied the capital approach to R&D, in which R&D expenditure is seen as an investment that contributes to the stock of R&D capital. Depreciation of the R&D capital stock was taken into account in connection with the obsolescence of knowledge. An annual 15% depreciation on the previous year's stock of R&D was assumed. This is a customary percentage in all the relevant literature.

The study shows that R&D has favourable effects on the business performance of R&D investors (6th and 7th arrows in Figure 4). According to the study, a 10% increase in R&D capital leads to a 2.5% extra value added, 2.0% extra employment and 0,5% extra labour productivity in the firms that carry out the R&D. The direct effect on demand plays a dominant role here. Although these percentages express the effects of a 10% higher R&D capital stock, they can also be interpreted as percentual effects of a structurally 10% higher level of R&D expenditure. When structurally 10% more R&D is carried out, the stock of R&D capital will in due course also be 10% higher.[11]

There has been little attention in the literature to the direct effect on demand. From the literature we see that it is common practice to measure the effect on productivity only. This is a serious limitation given that it does not take the characteristics of product innovations sufficiently into account. The study carried out by Van Leeuwen and Nieuwenhuijsen demonstrates that the direct effect on demand is a very important factor when analysing the effects of R&D on business performance. This is hardly surprising when we realise that approximately 70% of R&D expenditure in Dutch manufacturing is on product innovations.[12]

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11 Initially, the stock of R&D capital will increase quite strongly. However, because of the associated increase in depreciation this increase will progressively slow down. In due course, a new balance will be achieved and the stock of R&D capital will cease to grow. The new stock of R&D capital in that new balance will have grown just as much in terms of percentage as the R&D expenditure itself.

12 Van Leeuwen and Nieuwenhuijsen (1995).

7. Spillovers and total effects of R&D on business performance

In addition to the direct effects on the business performance of R&D investors, spillovers are important for the effects of R&D on business performance (5th, 8th and 9th arrows in Figure 4). Three different kinds of spillover can be distinguished: knowledge spillovers, 'rent' or market spillovers and network spillovers.[13]

Knowledge spillovers, also referred to as direct spillovers, occur if the knowledge developed by one firm becomes also available to other firms, for example by way of personnel moving from one employer to another, publications, informal contacts, or the reverse engineering of products. This knowledge can be used to copy or imitate innovations, and can also be used in a new innovation process and thus lead to a new technology. The second sort of spillover is the 'rent' or market spillover. These spillovers occur by way of transactions and are embodied in goods and services. Purchased goods are improved by the supplier's R&D activities, while this is often not fully reflected in the price. The third sort of spillovers are the network spillovers. These spillovers arise when the commercial or economic value of a new technology is dependent upon the development of related technologies. This concerns the synergy achieved if the innovations of different firms are complementary.[14]

A great deal of research has been carried out world-wide into R&D spillovers. This research is practically always concerned with the productivity effects of R&D. Spillover effects on the demand side are almost completely ignored in the literature. Furthermore, spillover effects are usually measured at sectoral level. Spillovers among firms operating in the same sector are then incorporated in the effects of the sector's own R&D. While the actual results of the various studies appear to differ considerably, in most studies a substantial spillover effect has been found.

Table 4 gives an overview of various studies, in which a distinction is made between the direct and the indirect rate of return to R&D. These rates of return reflect the marginal productivity of R&D capital, i.e. the extra production that becomes possible at a given input of labour and capital by increasing the R&D capital stock by a single unit. The direct rate of return to R&D is often referred to in the literature as the private return to R&D, which is the return to R&D carried out in the sector or firms itself. The indirect rate of return is the return outside the sector or firms itself, by way of spillovers. The direct and indirect return to R&D add up to the social rate of return to R&D.[15] While the

[13] Jaffe (1996), Haakman (1999).

[14] This, for instance, is the case in the ICT sector in which developments in hardware, content, IT services and (telecommunications) infrastructure tend to reinforce one another.

[15] These social returns are interpreted here as returns to the economy; the positive effects of new technologies on the environment and health care, for instance, are not taken into account.

table only gives a small selection of the studies carried out in this field, it does show that high values are generally found for both the private (the direct) return and the indirect return to business R&D.

Table 4 Direct and indirect rates of return to R&D; the results of various studies

Author(s)	Data	Period	Direct rate of return	Indirect rate of return
Terleckyj (1980)	20 manufacturing sectors in the US	1948-1966	25-27%	81-183%
Goto and Suzuki (1989)	50 sectors in Japan	1978-1983	26%	80%
Griliches and Lichtenberg (1984)	193 manufacturing sectors in the US	1959-1968 1964-1973 1969-1978	20-76% 11-58% 30-31%	insignificant 90% insignificant
Scherer (1982, 1984)	87 sectors in the US	1964-1969 1973-1978	insignificant 29-43%	64-74% 71-147%
Van Meijl (1995)	30 sectors in France	1978-1992	15-30%	47%-480%

Source: Roelandt, Gerbrands, Van Dalen and Van Sinderen (1996) and Grosfeld (1997).

Mohnen (1996), on the basis of an extensive literature overview, concludes that the spillover effects set out in the literature average about 50 to 100% of the direct effects. In other words: the social returns to R&D are, on average, 50-100% higher than the private return for the firm or the sector actually carrying out the R&D. In a previous literature overview, Nadiri (1993) reaches similar conclusions regarding the magnitude of the spillovers. He concludes that the private rate of return to R&D in the literature comes up to an average of 20-30%, and that the social rates of return often vary from 20 to over 100%, with an average somewhere close to 50%.

Mohnen (1996) adds to the results found in the literature that the social rates of return are often underestimated given that the spillovers are usually only calculated for a limited number of sectors and/or firms. Spillovers to the services sectors are rarely taken into account, while it are the services sectors in particular that 'absorbs' a great deal of the technology from manufacturing sectors.

With regard to the Netherlands, research into spillovers is still scarce. Two studies were recently published in which the spillovers of R&D were measured for the Netherlands. These are the studies of Jacobs, Nahuis and Tang (1998, 1999) and Soete and Ter Weel (1999). Calculations were made in these studies of the average values of the influence of a sector's own R&D, and that of the R&D from other sectors. Soete and Ter Weel restricted themselves to knowledge spillovers, in which the flows of knowledge between the different sectors are modelled on the basis of a technology flow matrix; use was made of the patent figures issued by the European Patents Office (EPO). In the study carried out by Jacobs, Nahuis and Tang, an attempt was made to measure both knowledge and market spillovers, but the methodology followed by these authors mainly concerns market spillovers given that the relationships between the different sectors are modelled on the basis of intermediate deliveries.

The study carried out by Jacobs, Nahuis and Tang covers the whole business sector, in which a distinction is made between seven manufacturing and four non-manufacturing sectors. The study carried out by Soete and Ter Weel looks only at the manufacturing industry, which for the purpose of the study is divided into 22 sectors. Both studies investigate the effects of R&D on the total factor productivity, i.e. the potential production at a given input of labour and capital in the production process. Neither of these studies pays attention to direct effects on demand.

Both studies investigate the effect of a sector's own R&D on the total factor productivity and the effect of R&D carried out in other sectors. The capital approach to R&D is taken, in which the R&D expenditure in successive years contributes to the stock of R&D capital. Depreciation is taken into account. Both studies assume an annual depreciation of 15% on the R&D stocks of the previous year.

Soete and Ter Weel (1999) found an elasticity of 0.07 for R&D carried out in the sector itself, and a 0.10 elasticity for R&D carried out in other sectors. This means that a 10% increase in R&D expenditure in all manufacturing sectors in the longer term (when the higher level of R&D expenditure has been fully accumulated in the stock of R&D capital) would have a total effect of 1.7% on the total factor productivity in manufacturing, the greater part of which, namely 1.0%, can be attributed to spillovers between the different sectors.

Jacobs, Nahuis and Tang (1998, 1999) found much larger effects. For R&D carried out in the sector itself they estimated an elasticity of 0.35 and for R&D carried out in other sectors they estimated an average elasticity of 0.18. Considering that these estimates relate to the whole business sector this means that a 10% increase in R&D expenditure in all sectors of the Dutch business sector would, in due course, lead to a 5.3% increase in the total factor productivity of the business sector in the Netherlands. This result is high in comparison with other research. Of note is that the R&D expenditures in the services sector have a major effect on the total factor productivity of the Dutch business sector according to the estimation results, while it only makes up for a limited part of the total R&D expenditure carried out by firms in the Netherlands (about 20%). This can be queried from a theoretical point of view.

A study carried out by Coe and Helpman (1995) is also of relevance to obtain an indication of the effect of R&D on the total factor productivity of the whole business sector. On the basis of a regression analysis for 22 OECD countries, including the Netherlands, Coe and Helpman investigated the effect on a country's total factor productivity of R&D carried out in the domestic business sector and R&D carried out abroad. They made a distinction between the G7 countries and 15 smaller countries. This was done because spillovers from abroad will be relatively more important for the total factor productivity for smaller countries than for large countries, and the effect of one's own R&D will be less in smaller countries because the spillovers in smaller countries will to a large extent fall abroad. This is confirmed in the results of the regression analysis. For the G7 countries Coe and Helpman found an elasticity of 0.234 for R&D carried out in one's own country. For the 15 smaller countries, this elasticity is 0.078.[16] The latter implies that 10% extra business R&D in the Netherlands would in due course lead to a 0.78% higher total factor productivity in the Dutch business sector. This was based on an annual 5% depreciation on R&D capital. If, as an alternative, the more customary percentage of 15 is used, then the elasticity for domestic R&D for the 15 smaller countries stands as 0.109 and for the G7 countries at 0.247.

As was stated in Chapter 6, very little attention has been devoted to the direct effects on demand in the international literature. At the macro level it is particularly the direct effects on demand in terms of export that are important given that they lead to a larger total demand for domestic products. Direct demand effects on competing imports are also relevant, but quantitatively of less importance. There are two empirical studies available that provide an indication of the magnitude of the direct effects of R&D on the export demand for the Netherlands: one study conducted by Ioannidis and Schreyer (1998) for 22 individual manufacturing sectors, and one by Van der Linden (1997) at the macro level.

In a regression analysis for 10 OECD countries, including the Netherlands, Ioannidis en Schreyer (1998) investigated the direct effect of R&D on the export market share in 22 different manufacturing sectors. A distinction was made between 11 high-tech and 11 low-tech sectors. Whether a sector belongs to a high-tech or a low-tech sector is determined on the basis of the sector's R&D intensity. The R&D variable used was the relative stock of R&D capital which was defined as the stock of R&D capital in one's own country relative to the trade-weighted average of foreign competitors. The effects were measured as elasticities, and while the elasticities found for the different sectors apparently differed quite substantially, a significant effect was found for 9 of the 22 sectors. This applies for 8 of the 11 high-tech sectors. A total picture for the whole of manufacturing can be obtained by weighting the elasticities found for the various sectors on the basis of the share of these sectors in the total exports of the

16 The elasticity for foreign R&D in Coe and Helpman's study depends on a country's import share in GDP. For instance: this is calculated at 0.033 for the US and for the Netherlands at 0.158 (based on the year 1990).

manufacturing industries. This weighted elasticity is indicative of how much the export demand would increase in the whole of manufacturing if in all sectors the stock of R&D capital were to increase by 1%. For the Netherlands this results in a weighted elasticity of 0.36.[17] In other words: a 10% extra R&D capital in all sectors of Dutch manufacturing (to be achieved in the longer term through a 10% structural increase in R&D expenditure) would have a 3.6% direct effect on Dutch manufacturing's exports. Ioannidis and Schreyer also made an attempt to find spillovers in this sense between the various sectors, but these could not be detected. However, there may be no significant conclusions drawn in this respect because, as indicated by Ioannidis and Schreyer, this may be caused by measurement and econometric problems.

In a regression analysis at the macro level, Van der Linden (1997) studied the direct effect of the relative R&D capital stock (the R&D capital in one's own country in comparison with a weighted average of the competitors) on a nation's export performance. The extent to which the relative stock of R&D capital in the business sector directly influences a country's export performance was investigated for 15 countries, including the Netherlands. A significant effect was observed. We can deduce from the best explanatory equation that 10% additional business R&D in the Netherlands would have a 6.0% direct effect on Dutch exports in the longer term.[18]

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17 Source for the export shares: OECD (1999), p. 172-173. These export shares relate to the year 1996.

18 This is based on the level of R&D expenditure in the business sector in the Netherlands in 1997.

8. Macroeconomic effects of business R&D

Several studies into the productivity effects and the direct effects of business R&D on the export demand were discussed in the previous chapter. Table 5 sets out the implications of these studies in terms of productivity and exports from a (structural) 10% increase in R&D expenditure among Dutch enterprises.

Table 5 The long-term effects of 10% more business R&D in the Netherlands according to various studies

	Increase in the total factor productivity (%)	Increase in export demand (%)
Soete and Ter Weel (1999)	1.7 (manufacturing)	
Jacobs, Nahuis and Tang (1999)	5.3	
Coe and Helpman (1995)	0.78-1.09	
Ioannidis and Schreyer (1998)		3.6 (manufacturing)
Van der Linden (1997)		6.0

The next question to ask is how a productivity effect and a direct effect on export demand affect the economy (10th and 11th arrows in the diagram shown in Figure 4). A macroeconomic model can be used to obtain an insight into this effect. This chapter presents a picture of the macroeconomic effect of business R&D based on a simulation using the MESEMET-2 model. This is an updated and extended version of MESEMET ('MacroEconomic Semi Equilibrium Model with Endogenous Technology'), developed several years ago by the Dutch Ministry of Economic Affairs.[19] Before looking at MESEMET-2 in greater detail, let us first of all take a look at MESEMET.

MESEMET is an applied equilibrium model in which the relationship between technology and the economy is modelled comprehensively. This is an upgraded version of the MESEM model developed by Van Sinderen (1990, 1993) which incorporates technology and builds further on the previous model-based analyses of Den Butter and Wollmer (1992) and Den Butter and Van Zijp (1995). The model is based on theory and empirical studies in the literature and takes 1992 as the base year. MESEMET was inspired by the new (modern) growth theory in the sense that technological development is regarded as an endogenous factor, dependent on economic variables. Technology in the traditional neo-classical growth theory is exogenous. In this view, technological development is realised outside the economy and descends upon the economy as 'manna from heaven'.

19 Van Bergeijk, Van Dijk, Haffner, Van Hagen, De Mooij and Waasdorp (1995), Van Bergeijk, Van Hagen, De Mooij and Van Sinderen (1997), Van Hagen (1994).

In MESEMET, a higher level of R&D intensity raises the level of GDP but not the long-term growth rate of the economy. This is contrary to the endogenous growth models that have emerged from the new growth theory in which economic growth is permanently higher. This is connected with the production function on which MESEMET is based, namely a (nested) production function with constant returns to scale in labour and the different sorts of capital, i.e. physical capital, technology capital and human capital. Endogenous growth models are based on constant returns to scale in the various kinds of capital only (the so-called reproducible production factors, as distinguished from the non-reproducible production factor of labour) which in this view is the result of the positive externalities (spillovers) of knowledge development.[20] In this regard, a more traditional approach was chosen for in MESEMET because – as yet – empirical research has provided little support for the hypothesis of the endogenous growth models (Van Bergeijk et al, 1995, p. 12).

Both R&D's productivity effect and the direct effect on the export demand are taken into account in MESEMET. To this end, the stock of technology capital (which is largely equivalent to the stock of business R&D capital) is included in the equations for the production capacity and in the exports equation. In the Netherlands, the stock of technology capital is assumed to consist for 80% of business R&D capital and for 20% of R&D capital of (semi) public institutes. This percentage for the (semi) public sector is considerably lower than the sector's share in the total R&D expenditure in the Netherlands (45% in 1997). The reason is that (semi) public R&D is only partly geared towards the business sector and consequently only partly contributes to the production capacity and the business sector's innovative capability.

The productivity effect of R&D in MESEMET is based on empirical results taken from the literature. In MESEMET, a 10% increase in the stock of business R&D capital leads to a 0.9% higher total factor productivity in the business sector. Of this, 0.7% is a direct effect of the extra R&D, while 0.2% is the result of a side-effect on the stock of human capital. This takes into account a positive effect of R&D activities at the knowledge level of workers (learning by designing); a positive effect which is subsequently to the benefit of productivity. The productivity effect of 0.9% included in MESEMET is in line with the empirical results for the Netherlands found by Coe and Helpman (1995). It is also in line with the effect observed by Soete and Ter Weel (1999) for manufacturing industries. However, the result for the total business sector arrived at by Jacobs, Nahuis and Tang (1999) is far above this figure.

While the literature offered no directly usable empirical estimates for the direct effect on the export demand at the time of constructing the MESEMET model, various empirical studies did show an important effect of technology on the exports position. MESEMET takes into account a direct effect of R&D on the export demand by including the relative stock of technology capital in the exports equation. This variable,

[20] See, for instance, SER (1995), pp. 22-25.

referred to as the relative innovation capacity, expresses the stock of technology capital in the Netherlands compared with that of foreign countries. Prior to this, Den Butter and Van Zijp (1995) made use of theoretical insights to estimate the elasticity for a similar variable at 1.0. MESEMET presented something in line with this, the difference being that in addition to the relative stock of technology capital, the relative stock of human capital is also taken into account because it may be expected that this too will have a direct effect on the export demand. The underlying idea is that not all improvements in quality are the result of specific R&D efforts, but that, more generally, the knowledge level of the labour force will also exert an influence in this respect. In conformity with Den Butter and Van Zijp (1995), the sum of the elasticities of both direct demand effects in MESEMET is set at 1.0. This implies that a 10% increase in both the relative stock of technology capital and the relative stock of human capital also has a 10% positive effect on exports. An elasticity of 0.4% has been chosen for the relative stock of human capital. According to a study carried out by Reininga (1994) this is the share of human capital in Dutch exports. An elasticity of 0.6 was subsequently taken for the relative stock of technology capital.

Considering that the share of business R&D capital in the total stock of technology capital in the Netherlands is set at 80%, the elasticity of 0.6 for the relative stock of technology capital in the exports equation results in an exports elasticity for business R&D capital of 0.48. This means that a structural increase in business R&D expenditure in the Netherlands (in comparison with abroad) of 10% will, according to MESEMET, have a 4.8% direct effect on exports in the longer term. This percentage is well in line with the outcomes (shown in Table 5) of the studies carried out by Ioannidis and Schreyer (1998) and Van der Linden (1997) after MESEMET had been developed. The outcomes of these two studies confirm that R&D has a significant direct effect on the export demand and also underpin the elasticity chosen in MESEMET for the direct effect of technology capital on the exports position.

The original MESEMET was updated and extended in MESEMET-2.[21] The original model was calibrated with 1992 as the base year. In MESEMET-2 the base year is 1997. This is the most recent year over which R&D data are available.[22] The main extension in MESEMET-2 is that the empirically estimated equation for R&D expenditure by enterprises of Donselaar and Knoester (1999) was incorporated in the model (for this equation see Table 3 in Chapter 5). The explanatory variables in this equation were linked to other variables in the model. For instance: the solvency of enterprises was made dependent on the profit ratio and subsequently related to the model's original

21 Donselaar, Van Sinderen and Verbruggen (2000).

22 Data published in CBS (1999).

profit variable, the capital income of enterprises.[23] In addition to this extension of the model, other components of the model were also refined. Equations for production capacity and exports equations were basically left unchanged. Also in MESEMET-2 does a 10% extra business R&D have a 0.9% positive effect on the total factor productivity in the longer term, and a 4.8% direct effect on the export demand. The main equations for simulations with respect to R&D are set out in Appendix 1.

Table 6 Simulation with MESEMET-2; the effects of 10% more business R&D in the Netherlands (cumulated deviations from the base path; model version with exogenous business R&D)

		1	5	10	20	Long term
gross value added enterprises (volume)	%	0.17	0.69	0.98	1.16	1.20
gross domestic product (volume)	%	0.15	0.61	0.86	1.02	1.06
exports of goods and services (volume)	%	0.52	1.78	2.41	2.77	2.86
imports of goods and services (volume)	%	0.41	1.59	2.25	2.60	2.67
private consumption (volume)	%	0.04	0.48	0.94	1.19	1.24
gross investment enterprises (volume)	%	0.40	1.15	0.99	0.87	0.84
R&D expenditure enterprises (volume)	%	10.00	10.00	10.00	10.00	10.00
stock of technology capital enterprises (volume)	%	1.80	6.29	8.63	9.81	10.00
stock of human capital (volume)	%	0.06	0.32	0.51	0.66	0.73
stock of physical capital enterprises (volume)[1]	%	0.03	0.38	0.60	0.74	0.77
labour supply	%	0.10	0.19	0.19	0.19	0.19
employment enterprises	%	0.15	0.25	0.25	0.23	0.23
unemployment (% of labour supply)	Δ	-0.03	-0.03	-0.02	-0.01	-0.01
labour productivity enterprises	%	0.02	0.44	0.73	0.92	0.97
nominal gross wage rate enterprises	%	0.31	1.68	2.64	3.19	3.31
real gross wage rate enterprises	%	0.13	1.00	1.67	2.09	2.20
price of domestic goods and services	%	0.18	0.68	0.97	1.10	1.11
price of value added enterprises	%	0.32	1.20	1.69	1.93	1.95
gross capital income enterprises (real)	%	0.38	1.12	1.27	1.29	1.26
budget balance government (% GDP)	Δ	0.12	0.48	0.68	0.80	0.83
current account of balance of payments (% GDP)	Δ	0.19	0.58	0.74	0.84	0.86

[1] Excluding physical capital related to R&D.

[23] In MESEMET-2 solvency is related to the profit ratio on the basis of the following empirical relationship taken from the study carried out by Donselaar and Knoester (1999): $SOL = 0{,}148\ WQ + 0{,}673\ SOL_{t-1} + 13{,}07$. SOL denotes solvency and WQ the profit ratio which is defined as the net profit from production in the Netherlands as a percentage of the net value added (also see Kusters, 1994).

Table 6 presents the outcomes of a simulation using MESEMET-2 and reveals the effects of business R&D in the model. A model version was used for this simulation in which the R&D expenditure is exogenous. This implies that there is no feedback in the model via the R&D expenditure itself.

A 10% increase in business R&D (structural, i.e. the higher level continues year-in-year-out), according to MESEMET-2, results in the longer term in a 1.20% extra gross value added in the business sector. This beneficial effect is realised in particular via higher exports, which, in the longer term, will rise by 2.86%. The higher export level is due partly to the direct effect on the export demand, and partly to the higher total factor productivity which increases production capacity.

While the direct effect on demand has a direct effect on exports it also leads to a higher price level as a result of the increased demand. Therefore, the ultimate effect on exports is much smaller than the original impulse from the direct effect on exports. The larger production capacity has, on the contrary, a downward effect on the price level. This means that, on balance, the price level increase is limited and thus the extra production that becomes possible due to the higher production capacity can also be sold. On balance, the domestic price level increases by 1.11% in the longer term.

The higher domestic price level means that a terms of trade gain is achieved in the business sector and this has a positive influence on profitability. In combination with the higher production volume, this leads – because of higher investments – to a 0.77% increase in the physical stock of capital goods in the business sector (excluding physical capital related to R&D). The larger stock of capital goods subsequently contributes to the production capacity of enterprises.

The effect on the supply of labour is also important for the ultimate effect on production capacity. The model assumes a fully clearing labour market in the longer term, and thus the reaction of the labour supply in the longer term is determinative for the effect on the employment situation. In the simulation, the supply of labour increases in the longer term by 0.19%, resulting in a 0.23% increase in employment in enterprises. Decisive for the effect on the supply of labour is the change in the real gross wage rate. This variable increases in the simulation by 2.20% in the longer term, having been made possible by the increase in labour productivity and the terms of trade gain, two elements that generate financial leeway for a higher gross salary for employees.

In the longer term, the higher real wages (plus linked benefits) lead to a substantial increase in private consumption, 1.24%, which in turn gives an extra impulse to the demand. The increased expenditure, plus the price increase on the domestic market, lead to a considerable increase in imports which, calculated in volumes, increases almost as strongly as the exports. However, the terms of trade gain gives rise to a 0.86% increase in the balance of the current account of the balance of payments in the longer term.

The budget balance of the government also improves considerably; by 0.83% of the GDP in the longer term. The higher real wages play a major role here. After all, higher wages lead to higher taxes and social security contributions for the government, and the increased production volume obviously makes a significant contribution as well. We see quite clearly here that extra R&D has a very beneficial effect on the budget balance of the government.

Although the effect on the gross value added in the business sector of 1.20% in the longer term may be qualified as very beneficial, the effect on employment is limited. This is due to the fact that MESEMET-2 is a general equilibrium model in which it is assumed that the labour market will clear completely in due course by way of wage adjustments (a strong Phillips curve effect). Initially, the higher level of R&D expenditure has an important beneficial effect on employment, particularly because of the direct effect on the export demand. This effect declines in due course because of the wage adjustments.

However, whether the labour market really (always) will clear completely is still open to discussion. For instance, the CPB analyses are currently based on a wage equation in which the level of unemployment does not keep the wage rate down until the labour market fully clears, as in MESEMET-2, but in which the unemployment level only has a once-only effect on a wage rate that will be achieved in the longer term (a weak Phillips curve effect).[24] If such a wage equation is applicable, then an increase in employment will result in the longer term as appears from a sensitivity analysis made with MESEMET-2 using an alternative wage equation (see Appendix 2). The value added then also increases more than is the case with a fully clearing labour market.

When interpreting the results we furthermore must realise that MESEMET-2 is a linear model, calibrated on the basis of the situation in 1997. Consequently, the model is less suited to simulate major changes from the base path. This means that the model can be used to simulate the effects of, for example, 10% more business R&D, but is not intended for very large impulses of, say, 100%. In such a case, diminishing returns from R&D must be taken into account. The more R&D is carried out, the less the effects of extra R&D that are to be expected. Hall (1996) states that the most highly promising projects are selected first before moving down to projects with less profitable prospects. Kealy (1996) puts forward the argument that technology is becoming constantly more complex, and consequently firms have to invest higher and higher sums in R&D in order to make progress.[25] Because of the diminishing returns from R&D, the effects of a 100% extra R&D can be considerably less than 10 times the effect of a 10% extra R&D.

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24 See for example CPB (1997).

25 Conversely, as indicated by Bartelsman and Hinloopen (2000), ICT could again increase the returns from R&D.

9. Macroeconomic effects of government incentives for business R&D

Given the amount of business R&D in the Netherlands (1.413% of the gross value added in enterprises in 1997) the result of the simulation presented in Chapter 8 implies that, in the longer term, one guilder extra in R&D will produce 8.5 guilders worth of extra value added in enterprises in the Netherlands.[26] The subsequent question is: what is the effect of government R&D incentives? To calculate this, the empirically-estimated R&D equation in the study conducted by Donselaar and Knoester (1999) has been incorporated in MESEMET-2.

As stated in the foregoing, Donselaar and Knoester's study came up with a multiplier of 1.04 for the effect of government incentives on R&D expenditure in the business sector.[27] Besides, government financing of business R&D also has a direct positive effect on the profitability of firms, and this subsequently has a positive effect on the solvency of enterprises, one of the other variables in the empirically-estimated R&D equation. In addition to these direct effects of government financing of business R&D, the feedback effects on R&D expenditure are also important (12th arrow in the diagram shown in Figure 4). The main one being the positive effect on R&D expenditure that results from an increase in value added.[28] Finally, it is important that the higher level of profitability, as a result of the government financing of business R&D, also has a positive influence on fixed capital formation by enterprises which in turn has a favourable effect on the economy.

Table 7 shows the results of a simulation made with MESEMET-2 in which the effects of government R&D incentives are quantified. The simulation presents the effects of government R&D incentives amounting to 0.1% of the gross value added (at factor costs) in enterprises which, on the basis of the gross value added in 1997, is NLG 579 million (= 7% of R&D expenditure by enterprises).

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26 The simulation was based on an assumed 10% higher business R&D which, on the basis of the base year 1997, is 0.1413% of the gross value added in enterprises. This impulse has an effect of 1.20% in the longer term on the gross value added in enterprises: 8.5 times as high as the increase in R&D expenditure.

27 The multiplier of 1.04 was the result of an empirical estimate for the business sector exclusive of the Big Five firms. This was deemed applicable for the total business sector in MESEMET-2. It is not known how the multiplier for the Big Five firms relates to that for the other firms. Due to the lack of this information it was decided to use the same multiplier for the Big Five firms as for the other firms.

28 This is taken into account in the empirically-estimated R&D equation by expressing the R&D variable as a percentage of the gross value added in enterprises. This implies an elasticity of 1.0 between the amount of gross value added and R&D expenditure.

Table 7 Simulation with MESEMET-2; the effects of government R&D incentives amounting to 0.1% of the gross value added of enterprises (cumulated deviations from the base path; model version with endogenous business R&D)

		1	5	10	20	Long term
gross value added enterprises (volume)	%	0.07	0.48	0.75	0.92	0.98
gross domestic product (volume)	%	0.06	0.43	0.66	0.81	0.86
exports of goods and services (volume)	%	0.18	1.17	1.75	2.09	2.17
imports of goods and services (volume)	%	0.17	1.12	1.71	2.03	2.09
private consumption (volume)	%	0.03	0.37	0.77	1.00	1.05
gross investment enterprises (volume)	%	0.22	1.04	0.91	0.84	0.85
R&D expenditure enterprises (volume)	%	3.69	7.57	7.60	7.57	7.54
stock of technology capital enterprises (volume)	%	0.66	4.27	6.37	7.42	7.54
stock of human capital (volume)	%	0.02	0.23	0.40	0.54	0.61
stock of physical capital enterprises (volume)[1]	%	0.02	0.30	0.53	0.71	0.79
labour supply	%	0.04	0.14	0.15	0.15	0.16
employment enterprises	%	0.06	0.18	0.19	0.19	0.19
unemployment (% of labour supply)	Δ	-0.01	-0.02	-0.02	-0.01	-0.01
labour productivity enterprises	%	0.01	0.30	0.56	0.74	0.79
nominal gross wage rate enterprises	%	0.12	1.16	1.99	2.49	2.60
real gross wage rate enterprises	%	0.05	0.67	1.26	1.65	1.75
price of domestic goods and services	%	0.08	0.49	0.73	0.84	0.84
price of value added enterprises	%	0.13	0.85	1.28	1.48	1.48
gross capital income enterprises (real)	%	0.45	1.13	1.29	1.31	1.27
budget balance government (% GDP)	Δ	-0.01	0.27	0.46	0.57	0.60
current account of balance of payments (% GDP)	Δ	0.06	0.35	0.51	0.59	0.61

1 Excluding physical capital related to R&D.

The simulation shows as a result that the gross value added in the business sector rises by almost 1.0% in the longer term. This implies that, according to this simulation, one guilder spent on stimulating business R&D produces approximately 10 guilders extra in gross value added (at factor costs); this can be regarded as very favourable. It is obvious that this is primarily because of the favourable economic effects of business R&D, as we saw in the simulation in the previous chapter. In combination with a 1.04 multiplier for the effect of government R&D incentives on business R&D expenditure itself, R&D incentives have a very positive impact on the economy. It is also interesting to see that the budget balance of the government improves by 0.60% of the GDP in the longer term. In other words: the simulation shows that R&D incentives bring money in instead of costing the treasury money.

That the effects of a one-guilder incentive on the gross value added (9.8 guilders) is higher here than corresponds with 1.04 times the 8.5 guilders in extra value added produced in the longer term by one guilder extra in R&D we saw in the simulation in the previous chapter, can be attributed to the various indirect effects or by-effects of R&D incentives. First of all, the R&D expenditure in the simulation apparently increases slightly more than corresponds with the direct effect of government incentives on R&D expenditure in the business sector.[29] This is mainly because of the positive effect of the higher value added on business R&D expenditure. Secondly, it is important that the government financing of business R&D not only has a direct positive impact on business R&D, but also on fixed capital formation in enterprises thanks to a positive effect on the profitability. This latter effect is, in terms of magnitude, by far the most important one to explain the aforementioned difference.

To find out the importance of the various mechanisms for the simulation results, a sensitivity analysis is presented in Appendix 2. Four alternative versions of the model were studied to this end:

A. a model without a direct effect on the export demand;
B. a model in which the productivity effect of R&D is halved;
C. a model in which the multiplier for the effect of R&D incentives on business R&D expenditure is halved;
D. a model with a weak, as opposed to a strong Phillips curve effect in the wage equation, by which the labour market no longer clears completely in the longer term.

Although the results of the different versions of the model show substantial differences, they all still show very favourable economic effects. Without a direct effect on demand, the effect on the gross value added in enterprises is about one third less. The same applies if the productivity effect of R&D is halved. Halving the multiplier results in the effect on the gross value added being approximately 45% lower. Even in this case the economic effects of R&D incentives are still high. This means that the beneficial effects of R&D incentives do not so much depend on the exact value of the multiplier, but that the beneficial effects of R&D on the economy are determinative for the favourable economic effects that can be expected from R&D incentives. If a weak Phillips curve effect is used in the wage equation, then the effect on the gross value added rises by approximately one third. Employment in enterprises then increases substantially by 0.75%, as opposed to 0.19% in the simulation based on a strong Philips curve effect.

Subsequently, it is useful to compare stimulation of business R&D with other policy options. Table 8 shows such a comparison. The impulse in each simulation is 0.1% of

[29] In the longer term, R&D expenditure increases by 7.54% (calculated by volume and taking into account a real wage increase for R&D personnel of 1.75%, which is assumed to be equal to the real wage increase for all workers in the business sector), while the direct effect of government incentives on R&D expenditure is 7.36% (1.04 x 0.1/1.413, in which 1.413 is the R&D expenditure by enterprises in the original situation as a percentage of the gross value added in enterprises).

the gross value added in enterprises in the base year of MESEMET-2: 1997. The table sets out the long-term results of the following five policy options:

A. R&D stimulation in the business sector;
B. a reduction of tax on profits in the business sector;
C. a reduction in taxes and social security contributions on wages and social benefits;
D. an increase in (semi) public R&D;
E. an increase in educational expenditure.

Table 8 A comparison of different policy options using MESEMET-2; the long-term results of an impulse amounting to 0.1% of the gross value added in enterprises (cumulated deviations from the base path)

		A	B	C	D	E
Gross value added enterprises (volume)	%	0.98	0.11	0.04	0.47	0.22
Exports of goods and services (volume)	%	2.17	0.02	-0.03	0.93	0.37
Private consumption (volume)	%	1.05	0.17	0.18	0.37	0.10
Labour supply	%	0.16	0.01	0.04	0.09	0.05
Employment (enterprises + government)	%	0.16	0.01	0.04	0.09	0.06
Labour productivity enterprises	%	0.79	0.09	0.00	0.43	0.25
Real gross wage rate enterprises	%	1.75	0.14	0.03	0.98	0.62
Price of domestic goods and services	%	0.84	0.01	0.04	0.17	-0.10
Budget balance government (% GDP)	Δ	0.60	-0.04	-0.06	0.22	0.05

The simulations show that R&D stimulation in the business sector has the greatest economic effect. While an increase in (semi) public R&D and in educational expenditure also produces considerable effects, they are clearly less than from R&D incentives in the business sector. The reason being that R&D incentives are the most successful in promoting the innovation capacity of enterprises and in raising productivity. (Semi) public R&D and educational expenditure are only partly geared towards achieving this and consequently contribute less in this respect, on average. In addition to the economic goals, (semi) public R&D and educational expenditure are also geared towards broader social goals and should therefore not only be assessed on the economic effects. It goes without saying that a more targeted impulse for these two sorts of expenditure, focusing more on promoting the ability to innovate in the business sector, will have greater economic effects.

Lowering tax on profits and lowering tax and social security contributions on wages and social benefits make no substantial contribution towards productivity in the business sector and consequently have much less economic effects in the long term than the policy options described above. The difference in the economic effects is also expressed in the consequences for the budget balance of the government. On balance, R&D stimulation in enterprises, investments in (semi) public R&D and investments in education improve the financial position of the government, the tax policy options have a negative effect on the financial balance of the government.

Given the clearing labour market in the longer term in MESEMET-2, the economic effects of different policy measures in MESEMET-2 ultimately depend on the effects that appear in terms of labour productivity and the supply of labour. While the supply of labour increases to a limited extent in all simulations, the increase is the highest from R&D incentives. This is due to the considerable real wage increase, which is caused by the productivity effect and terms of trade gain.

All in all, Table 8 informs us that, when compared with other policy options, R&D incentives are a very effective means for the government to generate extra economic growth in the longer term. Considering the relatively strong effect of R&D on labour productivity in the business sector, R&D incentives also contribute to the desired transition in the growth pattern of the Dutch economy, namely from factor-driven growth to innovation-driven growth (see Chapter 2).

Another question is to what level should the government stimulate R&D expenditure in the business sector. It was already stated in the previous chapter that R&D has diminishing returns, and thus a certain social optimum will be attached to the total amount of R&D expenditure. What this optimum is, is difficult to say. However, something can be said in a more abstract sense about the subsidy percentage that would be optimal for R&D in terms of society. This can be done on the basis of the differences given in the literature between the social and the private return to R&D. The studies into spillovers discussed in Chapter 7 indicate that the social returns to business R&D are on average 1.5 to 2 times as high as the private returns achieved by the firms that actually carry out the R&D. In theory, this could justify a subsidy of 33-50% because then a reduction in the cost of R&D for firms is achieved that could bring the R&D expenditure by enterprises to the socially desired level.[30] The current level of a 9% average (see Table 2) is far below this level. It goes without saying that in the event of an eventual intensification of R&D incentives, other funding allocation options must be taken into account. However, the comparison of the policy options in Table 8 shows that stimulation of R&D in the business sector is a valid way to generate further growth in prosperity.

Although the model calculations indicate that the effects of R&D incentives are considerably more beneficial than those from a reduction in tax on profits, it may not be concluded that a reduction of the tax burden for enterprises would not be an effective means of stimulating economic activity. A considerable reduction of tax on profits, for instance by lowering the corporation tax rate from 35 to 30%, could also make a

30 If the social returns are twice as high as the private returns, a 50% reduction in the cost of R&D will be needed in the business sector to achieve the required social level. If the social returns are 1.5 times as high as the private return, this gives us a percentage of 33.

substantial contribution towards reinforcing the Dutch economy, partly because the corporation tax is important for the international location decisions of enterprises. Table 8 also shows that a reduction of the corporation tax has a positive effect on the economy. Nevertheless, the analysis also makes it quite clear that it would be unwise to reduce the corporation tax at the expense of R&D incentives. In other words, it is not so much a question of ‘or-or’ but rather one of ‘and-and’.

10. Conclusion

The economic effects of stimulating business R&D depend on many factors. It is not solely a matter of the extent to which government incentives lead to extra business R&D, but also – and particularly – of the direct and spillover effects of that extra R&D on the economy. Because of the increasing importance of innovative strength for structural economic development, empirical research into these effects has received a great deal of attention in recent years. Although a great deal of study still needs to be carried out in this field, the results to date allow us to make an empirically-based analysis of the effects of government policy geared towards promoting business R&D. In this paper we have placed the various sub-aspects that play a role in this respect into a total framework, both diagrammatically and in the form of a model.

A simulation with the general equilibrium model MESEMET-2 shows that stimulating business R&D is particularly effective. The simulation shows that a one-guilder extra government incentive for business R&D produces in the long term, converted for the year 1997, approximately 10 guilders-worth of extra gross value added in enterprises. This translates into a substantial increase in labour productivity. As a result of these beneficial economic effects the budget balance of the government will improve.

Our analysis shows that the economic effects of government incentives for business R&D are particularly beneficial; it also indicates the lines along which this result is achieved. The analysis also shows that R&D incentives lead to a higher labour productivity which, in turn, contributes to the desired transition in the growth pattern of the Dutch economy from ‘factor-driven’ growth to ‘innovation-driven’ growth.

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Appendix 1

The most important equations in MESEMET-2 for simulations with respect to R&D

Production capacity

$Yp^* = 0{,}66\, Lp_{eff} + 0{,}34\, Kp_{eff}$
$Lp_{eff} = 1/3\, Lp_{erd} + 2/3\, HC$
$Kp_{eff} = 0{,}85\, KT + 0{,}15\, Kg_{ex}$
$KT = 0{,}7\, Kp_{erd} + 0{,}3\, TC$
$TC = 0{,}8\, TCp + 0{,}2\, TCg$
$TCp = 0{,}82\, TCp(-1) + 0{,}18\, RDp$
$TCg = 0{,}82\, TCg(-1) + 0{,}18\, RDg$
$HC = 0{,}90\, HC(-1) + 0{,}055\, Eg_{au} + 0{,}030\, Ip_{erd} + 0{,}010\, RDg + 0{,}005\, RDp - 0{,}02\, Ti'$
$Yp^d = 0{,}4\, Yp + 0{,}3\, Yp(-1) + 0{,}2\, Yp(-2) + 0{,}1\, Yp(-3)$

Labour market

$Lp = 0{,}992\, Lp_{erd} + 0{,}008\, Lp_{rd}$
$Lp_{erd} = 0{,}9\, Lp_{erd}^d + 0{,}1\, Lsp_{erd}$
$Lp_{erd}^d = 0{,}55\, Yp^d + 0{,}45\, Lp_{eff} - 0{,}55\, Wp_y$
$Lp_{rd} = RDp$
$Ls = Ls_{au} + 0{,}15\, Wp_n' - 0{,}08\, (Yu_o - Ls_{au}) - 0{,}25\, Lu$
$Lsp_{erd} = 1{,}134\, Ls - 0{,}126\, Lg - 0{,}008\, Lp_{rd}$
$Lu_{en} = 18{,}2\, Ls - 15{,}2\, Lp - 2{,}0\, Lg$
$Lu = Lu_{en} + Lu_{au}$
$\Delta Lu_{\%Ls} = 0{,}055\, (Lu - Ls)$
$Pl = Pl(-1) + (P - P(-1)) + (H - H(-1)) + 0{,}25\, (Tlp - Tlp(-1)) - 0{,}25\, Lu_{en}$
$H = Yp - Lp$

Expenditure and production

$X = 0{,}739\, Cp + 0{,}167\, Ip + 0{,}063\, Gm + 0{,}031\, Ig$
$V = 0{,}571\, X + 0{,}429\, B$
$Yp = X + 0{,}75\, (B - M)$
$Yg = 0{,}783\, Lg + 0{,}217\, Dg$
$Yt = 0{,}880\, Yp + 0{,}120\, Yg$
$B = Mw_{au} - 2\, ER + 0{,}6\, RIC + 0{,}4\, RHC$
$M = V + 0{,}75\, ER$
$ER = P - Pf_{au}$
$RIC = TC - TCf_{au}$
$RHC = HC - HCf_{au}$
$P = 2/3\, (Lp + Pl) + 1/3\, (Yr + P - 0{,}0031\, ORp_{au}) - 0{,}75\, ER - Yp^*$
$Py = 1{,}75\, P - 0{,}75\, Pf_{au}$

R&D expenditure

RDp	$= 100\ \Delta RDp_{\%Yp}/1{,}4132 + (Yp + Py) - Prd$
$\Delta RDp_{\%Yp}$	$= 1{,}04\ (0{,}5\ \Delta ORp_{\%Yp} + 0{,}3\ \Delta ORp_{\%Yp}(-1) + 0{,}2\ \Delta ORp_{\%Yp}(-2)) +$ $1{,}18\ (0{,}5\ \Delta OUp_{\%Yp} + 0{,}5\ \Delta OUp_{\%Yp}(-1)) + 0{,}0065\ \Delta SOL(-2) -$ $0{,}009\ \Delta RREN + 0{,}0045\ \Delta INT(-1) + \Delta RDp_{\%Yp,au}$
$\Delta ORp_{\%Yp}$	$= 0{,}10358/100\ (ORp_{au} - Yp)$
ΔSOL	$= 0{,}148\ \Delta WQ + 0{,}673\ \Delta SOL(-1)$
Prd	$= 0{,}553\ Pl + 0{,}447\ P$
RDg	$= 0{,}8\ RDg_{r,au} + 0{,}2\ RDg_{op,au}$

Public finance

Ug	$= 0{,}457\ Yu_{exiab} + 0{,}021\ Yu_{iab} + 0{,}126\ Gm + 0{,}062\ Ig + 0{,}212\ (Lg + Wg) +$ $0{,}002\ ORp_{au} + 0{,}120\ Yo_{au}$
T_n	$= 0{,}844\ (Lp + Wp + Tlp) - 0{,}097\ PPp + 0{,}253\ (Yr + Tk'_{au})$
T	$= 0{,}783\ T_n + 0{,}106\ (Lg + Wg + Tlg) - 0{,}012\ PPg + 0{,}025\ (Yu_{exiabw} + Tuit_w) +$ $0{,}070\ (Wu + UGo_{au} + Tuit_{og}) + 0{,}025\ (Yu_{exiabo,au} + Tuit_{on}) +$ $0{,}003\ (Yu_{iab} + Tuit_{ia})$
$\Delta F_{\%Y}$	$= 0{,}444\ (T - Ug)$

Clarification

Variables printed in italics are in percentage changes, the other variables (preceded by a Δ) are in absolute changes. The additions (-1), (-2), etc., after the variables indicate lags, expressed in years.

The tax rates and tax revenue in the model include social security contributions and the balance of indirect taxes and subsidies.

The entire model is described in Working Paper 2000/01 of the Directorate General for Industry of the Ministry of Economic Affairs.[31]

[31] Donselaar, Van Sinderen and Verbruggen (2000).

List of symbols

B	Exports of goods and services (volume)
Cp	Private consumption (volume), including investments in dwellings and social benefits in kind[32]
Dg	Depreciation of government physical capital (volume)
Eg_{au}	Government expenditure on education (volume, exogenous)
ER	Relative price level in the Netherlands in comparison with abroad
$F_{\%Yt}$	Budget balance of the government as a percentage of GDP at factor costs
Gm	Net government consumption of goods and services (volume)
H	Labour productivity enterprises (volume)
HC	Stock of human capital (volume)
HCf_{au}	Stock of human capital abroad (volume, exogenous)
Ig	Gross investments government (volume)
INT	Internationalisation index for the Dutch economy (1990 = 100), in which the volume of the relevant world trade is expressed as a ratio to the volume of the gross value added (at factor costs) in enterprises
Ip	Gross investments enterprises (volume)
Ip_{erd}	Gross investments enterprises (volume), unrelated to R&D
Kg_{ex}	Government physical capital (volume), unrelated to education and R&D
Kp_{eff}	Effective capital input in the production process of enterprises (volume), including technology capital and government physical capital
Kp_{erd}	Physical capital in the business sector (volume), unrelated to R&D
KT	Effective capital input in the production process of enterprises (volume), including technology capital and excluding government physical capital
Lg	Employment government
Lp	Employment enterprises
Lp_{eff}	Effective labour input (including human capital) in the production process of enterprises (volume)
Lp_{erd}	Employment enterprises, excluding R&D personnel
Lp_{erd}^{d}	Labour demand enterprises, excluding R&D personnel
Lp_{rd}	Employment R&D personnel enterprises
Ls	Labour supply
Ls_{au}	Labour force (exogenous)
Lsp_{erd}	Labour supply available for enterprises, excluding R&D personnel
Lu	Unemployment
Lu_{au}	Exogenous (natural) unemployment
Lu_{en}	Endogenous unemployment

[32] Private consumption is defined more loosely here than in the National Accounts of the CBS. Investments in dwellings in the National Accounts are part of the investments in fixed assets (fixed capital formation), social benefits in kind have been recorded under the heading of governmental consumption expenditure since the revision of the National Accounts in 1999.

$Lu_{\%Ls}$	Unemployment as a percentage of labour supply
M	Imports of goods and services (volume)
Mw_{au}	Relevant world trade (volume, exogenous)
ORp_{au}	Government financing of business R&D from central government (real, exogenous)
$ORp_{\%Yp}$	Government financing of business R&D from central government as a percentage of the gross value added (at factor costs) in enterprises
$OUp_{\%Yp}$	Government financing of business R&D related to the contracting out of R&D by (semi) public research institutes, as a percentage of the gross value added (at factor costs) in enterprises
P	Price of domestic goods and services
Pf_{au}	Price of foreign goods and services (exogenous)
Pl	Nominal gross wage rate enterprises
PPg	Pension contributions government (real)
PPp	Pension contributions enterprises (real)
Prd	Price of R&D in enterprises
Py	Price of gross value added enterprises
RDg	R&D efforts in (semi) public institutes (volume)
$RDg_{op,au}$	R&D of (semi) public institutes assigned to them by third parties (volume, exogenous)
$RDg_{r,au}$	R&D of (semi) public institutes financed by the central government (volume, exogenous)
RDp	R&D efforts enterprises (volume)
$RDp_{\%Yp}$	R&D expenditure by enterprises as a percentage of the gross value added (at factor costs) of enterprises
$RDp_{\%Yp,au}$	Autonomous component of R&D expenditure by enterprises as a percentage of the gross value added (at factor costs) in enterprises
RHC	Relative stock of human capital in the Netherlands in comparison with abroad (volume)
RIC	Relative innovation capacity, defined as the relative stock of technology capital (volume) in the Netherlands in comparison with abroad
RREN	Real interest rate
SOL	Solvency of enterprises
T	Total tax revenue of the government (real)
TC	Domestic stock of technology capital (volume)
TCf_{au}	Foreign stock of technology capital (volume, exogenous)
TCg	Stock of technology capital built up by (semi) public institutes (volume)
TCp	Stock of technology capital built up by enterprises (volume)
Ti'	Marginal integrated tax rate on labour income (taxes and contributions + deductions in connection with income-dependent schemes)
Tk'_{au}	Marginal and average tax rate on the gross capital income of enterprises (exogenous)
Tlg	Average tax rate on labour income, government
Tlp	Average tax rate on labour income, enterprises
T_n	Total tax revenue (real), excluding taxes on labour income of government and social benefits

$Tuit_{ia}$	Average tax rate on social benefits by virtue of income-dependent schemes[33]
$Tuit_{og}$	Average tax rate on non-unemployment-related social benefits in cash (excluding benefits by virtue of income-dependent schemes)
$Tuit_{on}$	Average tax rate on non-unemployment-related social benefits in kind (excluding benefits by virtue of income-dependent schemes)
$Tuit_{w}$	Average tax rate on unemployment-related benefits (excluding benefits by virtue of income-dependent schemes)
Ug	Total government expenditure (real)
UGo_{au}	Recipients of non-unemployment-related social benefits in cash (exogenous)
V	Total expenditure (volume)
Wg	Real gross wage rate government
Wp	Real gross wage rate enterprises
Wp_{n}'	Effective real wage rate in enterprises (real wage rate in enterprises after deduction of taxes and contributions, and adjusted for deductions in connection with income-dependent schemes)
Wp_{y}	Real labour costs enterprises
WQ	Net profit ratio enterprises
Wu	Real benefit level of unemployment-related social benefits and non-unemployment-related social benefits in cash (excluding benefits by virtue of income-dependent schemes)
X	Total national expenditure (volume)
Yg	Gross value added at factor costs of the government (volume)
Yo_{au}	Balance of other payments made by government to enterprises and households (real, exogenous)
Yp	Gross value added at factor costs in enterprises (volume)
Yp*	Production capacity enterprises (volume)
Yp^{d}	Desired production capacity enterprises (volume)
Yr	Gross capital income enterprises (volume)
Yt	Gross domestic product at factor costs (volume)
Yu_{exiab}	Social benefits, excluding benefits by virtue of income-dependent schemes, gross (real)
$Yu_{exiabo,au}$	Yu_{exiab}, non-unemployment-related, in kind (real, exogenous)
Yu_{exiabw}	Yu_{exiab}, unemployment-related (real)
Yu_{iab}	Social benefits by virtue of income-dependent schemes, gross (real)
Yu_{o}	Basic amount in benefits by virtue of income-dependent schemes, net (real)

33 This only relates to the balance of indirect taxes and subsidies on private consumption. The same applies with regard to the variable $Tuit_{on}$.

Appendix 2

Sensitivity analysis MESEMET-2 for R&D incentives variant

Table A1 Sensitivity analysis of the long-term effects of government incentives for business R&D amounting to 0.1% of the gross value added in enterprises (cumulated deviations from the base path)

		Standard	A	B	C	D
gross value added enterprises (volume)	%	0.98	0.67	0.67	0.53	1.32
exports of goods and services (volume)	%	2.17	0.75	1.80	1.10	2.61
imports of goods and services (volume)	%	2.09	0.17	2.02	1.09	2.32
private consumption (volume)	%	1.05	0.29	0.95	0.59	1.18
gross investments enterprises (volume)	%	0.85	0.11	0.83	0.53	1.35
R&D expenditure enterprises (volume)	%	7.54	7.10	7.64	3.79	7.97
stock of technology capital enterprises (vol.)	%	7.54	7.10	7.64	3.79	7.97
stock of human capital (volume)	%	0.61	0.37	0.44	0.34	0.79
stock of physical capital enterprises (volume)[1]	%	0.79	0.06	0.78	0.50	1.30
labour supply	%	0.16	0.05	0.14	0.08	0.54
employment enterprises	%	0.19	0.06	0.16	0.10	0.75
unemployment (% of labour supply)	Δ	-0.01	0.00	-0.01	0.00	-0.12
labour productivity enterprises	%	0.79	0.61	0.51	0.43	0.56
real gross wage rate enterprises	%	1.75	0.58	1.53	0.93	1,22
price of domestic goods and services	%	0.84	-0.38	1.02	0.43	0.77
price of value added enterprises	%	1.48	-0.66	1.79	0.75	1.34
budget balance government (% GDP)	Δ	0.60	0.12	0.52	0.29	0.71
current account of balance of payments (% GDP)	Δ	0.61	0.13	0.53	0.29	0.69

[1] Excluding physical capital related to R&D.

Standard: standard version of MESEMET-2. A, B, C en D: adjusted versions of the model.

A Excluding the direct effect on export demand. Exports equation without the effect of RIC and RHC, i.e. $B = Mw_{au} - 2\,ER$.

B Productivity effect of business R&D and (semi) public R&D, halved. Equation for KT adjusted as follows: KT = 0,85 Kp_{erd} + 0,15 TC. Equation for HC adjusted as follows: HC = 0,90 HC(-1) + 0,0600 Eg_{au} + 0,0325 Ip_{erd} + 0,0050 RDg + 0,0025 RDp – 0,02 Ti'.

C Multiplier for the effect of R&D incentives on R&D expenditure in the business sector, halved. Coefficient for $\Delta ORp_{\%Yp}$ in equation for $\Delta RDp_{\%Yp}$ is now 0,52 instead of 1,04.

D In the wage equation, a weak instead of a strong Phillips curve effect. Equation for Pl adjusted as follows: $Pl = Py + 0{,}34\ (P - Py) + H + 0{,}25\ Tlp - 1{,}48\ \Delta Lu_{\%Ls}$. The coefficient for $\Delta Lu_{\%Ls}$ is taken from the wage equation in the JADE model of the CPB (1997). To do justice to the theoretical background of the CPB equation (bargaining model with endogenous equilibrium unemployment), the price variable P is replaced with $Py + 0.34\ (P - Py)$, in conformity with the CPB equation.