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ENERGY LEVIES AND ENDOGENOUS TECHNOLOGY IN AN EMPIRICAL SIMULATION MODEL FOR THE NETHERLANDS

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In this paper the economic effects of a regulating energy levy are illustrated using a small macro-economic empirical simulation model for The Netherlands, called the EnTech-model. The model is especially designed to reckon with the effects of changes in prices on the bias of technological progress. It appears that a so-called employment double dividend, i.e., increasing employment and decreasing energy use at the same time, can occur. A general levy yields stronger results than a levy on household use only. However, the stronger effects of a general levy on employment and energy use are accompanied by shrinking production and, under some scenarios, by decreasing disposable income of workers and/or non-workers. Furthermore, total R&D-expenditures decrease due to shrinking production. This latter effect can, however, be compensated using part of the proceeds of the levy. All in all, the effects of a regulating energy levy will not be very spectacular, considering the size of the levy.

Entech model

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A major economic policy question of today is to what extent (regulating) energy levies can contribute to a reduction of energy demand and hence of greenhouse gas emissions. The economic mechanisms which are set at work by the introduction of an energy levy and by the redistribution of the proceeds are rather complex, so that only a model based analysis is capable of calculating the net effects of such levies. Two different ways of modelling the effects of energy levies emerge from the literature. Firstly the analysis is conducted using highly aggregated, theoretical, general equilibrium models which concentrate on second best policies for energy taxation (see e.g. Bovenberg and Van der Ploeg, 1992, 1993, 1994 and Bovenberg and De Mooij, 1992, 1993). The second approach uses disaggregated empirical models which are either of the applied general equilibrium type (e.g. the GREEN-model of the OECD, see OECD, 1994) or are dynamic policy models in the Tinbergen tradition (e.g. the combined use of the SENECA energy model and the ATHENA multi-sector model by the Netherlands Central Planning Bureau (CPB, 1992) and the HERMES-model by the EC (see Laroui and Velthuijsen, 1992a, 1992b)).

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This paper illustrates the economic effects of energy levies and the redistribution of their proceeds using a relatively simple and aggregated empirical macroeconomic model for The Netherlands, called the EnTech-model, which intermediates between the two approaches sketched above. It is a small dynamic model inspired by endogenous growth theory. Total productive capacity is not only determined by physical capital and labour, but also by energy, technology capital, energy saving technology capital and human capital as factor inputs. Technology capital does not only enhance the productivity of physical capital, but there are also spill-overs to human capital. In this manner the model reckons both with the externalities of investment in R&D and with price effects on the bias of technical progress. It must be emphasized that our model is *not* an applied general equilibrium model. It may illustrate the dynamics of the introduction of an energy levy. Moreover, the parameter values of the model are based on empirical results of the literature and the model is calibrated in such a manner that a dynamic simulation over the past adequately reproduces the historical time path of the observed endogenous variables.

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The simulation experiments assess the consequences of an energy levy for economic activity, employment and technological innovation. On the one hand an energy levy, when introduced on a national level, may hurt the competitive position of a country, which has negative effects on economic activity and employment. On the other hand it may also stimulate energy saving technological innovation, which can improve the competitive position of the national industry and which may shift the bias of technical progress away from labour saving. Moreover, the proceeds of an energy levy can be used to decrease labour market taxes. In this context the

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energy tax may yield a so-called double dividend: it may improve the quality of the environment and increase employment at the same time. In that case the loss of employment because of the deterioration of the competitive position should be more than fully compensated by employment gains induced by the substitution of energy for other production factors including labour, by the reduction of labour costs, by the demand effects of the redistribution of the tax proceeds and by the shift from labour saving to energy saving technical progress. In our simulation experiment these underlying mechanisms are clarified further by a sensitivity analysis with respect to the key parameters of the model. The model allows to distinguish between the effects of a levy on industrial use of energy and a levy on private consumption of energy. Furthermore various ways of redistribution of the proceeds are considered.

Section 1 shortly surveys the literature on theoretical and empirical models of energy taxes. Section 2 provides an outline of the EnTech-model. Section 3 gives the results of our experiments and section 4 concludes.

1. Literature

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The major aim of a regulating energy levy is to evoke (zorgt voor) a behaviourial change which through substitution and through technological change induces a decrease of energy demand. Thus a regulating levy is *not* a Pigouvian tax which is raised in order to cover the costs of environmental damage, nor is it a general tax which aims at raising government income. Moreover, taxation is just one amongst many other instruments of environmental policy, such as subsidies, regulations, information, emission standards and marketable emission permits (see e.g. Sterner, 1990, for a short review). In this paper we only consider the *regulating energy levy* as it is the major instrument in the policy proposals of, e.g., the EC and the Dutch government, which aim at curbing (beteugelen) energy consumption and greenhouse gas emissions[1]. In the case of regulating levies, the redistribution of the proceeds should foster (bevorderen) fiscal neutrality. An open question in the proposals is whether there should be *ex ante* or *ex post* fiscal neutrality. The first approach implies the redistribution of the current proceeds of the levy only, whereas according to the second approach all net revenues are to be redistributed: both the current proceeds and the endogenously determined and possibly negative indirect revenues. Theoretically the latter approach is most elegant, but in practice it will be difficult to determine the endogenous component of the revenues. However, in our model exercises we consider *ex post* budget neutrality.

1.1 Theoretical literature

The effects of energy taxes on environmental quality, economic activity and employment have been investigated both by means of theoretical models and empirical models. In the theoretical literature general equilibrium models play a major role. Bovenberg and others consider the effects of energy levies in the context of general equilibrium models. In a number of papers Bovenberg and Van der Ploeg (e.g. Bovenberg and Van der Ploeg, 1992, 1993, 1994) analyse the effects of environmental policies in a second best framework of a small open economy. It appears that the occurrence of an employment double dividend, i.e. a cleaner environment and increasing employment at the same time, is strongly dependent upon the existence of a fixed factor in production. In a model with only two production factors, labour and resources, where the price of resources is exogenously given by the world market price, labour, not surprisingly, always bears the whole tax burden. Replacing a labour tax with a resource tax in this case amounts to replacing an explicit tax on labour with an implicit tax on labour. However, when there is a fixed factor of production, part of the costs of an environmental tax can be shifted to this fixed factor. This suggests that an employment double dividend is more likely in the short run than in the long run, since in the short run more factors are fixed. It appears that the larger the share of the fixed factor in production, the lower the profit tax and the larger the substitution possibilities between labour and resources, the easier to shift the costs of an environmental tax to the fixed factor and the more likely an employment double dividend will be.

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Bovenberg and De Mooij (e.g. Bovenberg and De Mooij, 1992, 1993) also analyse the effects of environmental taxes in a general equilibrium framework. They allow for the existence of income transfers provided by the government. In their model an employment double dividend can appear even when there is perfect international capital mobility. In fact, workers are able to shift part of the burden of the environmental tax to transfer recipients and owners of financial wealth. In order to illustrate this mechanism Bovenberg and De Mooij (1993) provide a numerical simulation again using a model of a small open economy facing exogenous world market prices for commodities and capital. In this model two classes of households, differing with respect to their sources of income, are explicitly modelled. The model is calibrated using Dutch data for 1989. It appears that a broad based energy tax on both firms and households yields a (weak) double dividend at the expense of a fall in non-labour income.

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1.2 Empirical studies

A number of empirical exercises using large macro-economic models have been conducted in order to calculate the consequences of energy levies on energy use and greenhouse gas emp model [illegible] change to [illegible]

emissions and economic growth. However, the outcomes of these exercises are difficult to compare because they relate to different types of measures, to various levels at which the measures are to be taken (worldwide, OECD, European Union, national), and because the baselines used for the model simulations differ from each other. Moreover, most model simulations focus on the effectiveness of the energy levies for the reduction of emissions and do not explicitly take labour market developments into consideration. This holds true for the exercises using the global GREEN model (OECD, 1994), an applied general equilibrium model, which calculate the level of carbon taxes per region needed in order to comply under different scenario's with a global Toronto type agreement. By 2020, the tax, averaged over all regions, should be $215 per ton of carbon (in 1985$), but varies widely amongst regions, from $955 per ton in the pacific basin to $63 in China (see also Bradley and Fitzgerald, 1992).

On the other hand, the recent 'White Book' of the European Commission (EC, 1993) focusses on the relation between the labour market (employment) and economic growth. It presents the results of simulation exercises on the effects on employment of a reduction of the employer's contribution to social security financed by an energy levy and/or increasing the value added tax, using three different models. According to the global QUEST-model of the European Community this package of measures has, for the cummunity as a whole, a negative effect on employment. The results using the MIMIC-model, an applied general equilibrium model for The Netherlands, are mixed and depend upon the type of redistribution scheme. The linked multi-sectoral HERMES-model shows moderate positive employment effects of a regulating energy levy in six EC-member states.

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Finally, the Dutch Central Planning Bureau (CPB, 1992) has made calculations on the effects of a 50% and a 100% levy, imposed at the OECD or national level[2]. According to these calculations the competitive position of many energy-intensive industries is dramatically affected in the 'going-alone' scenario in case of a general energy levy, and a broader geographical base (OECD) does not contribute sufficiently to the solution of this problem for industries in the exposed sector. According to these calculations, employment decreases considerably in case of a general levy, whereas the impact of a household levy on employment is virtually nil.

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All in all, these model exercises do not show any convergency of evidence with respect to the double dividend hypothesis. Yet, it is obvious that the energy levy is more efficient in reducing greenhouse gas emissions when it is effectuated at a worldwide level rather than at a Western European or national level. In the latter case the influence of industries closing down and/or moving abroad is larger so that the competitive position deteriorates. The resulting decrease of economic activity (very [illegible]) mitigates the possible positive effects on employment of the redistribution of the proceeds of the levy.

Differences between the outcomes of these model exercises also emerge because of differences in the implementation of the measures in the model and because of differences in modelling the major mechanisms. For instance, the Central Planning Bureau explicitly reckons with the effects of industries moving abroad using additional information not contained in the model, whereas in other models, including ours, moving abroad and closing down of industries is implicitly described by substitution in the production function. Furthermore, the effect of higher energy prices on the bias of technological progress is not implemented in most models, or in a very superficial manner. One of the major features of our EnTech-model is to endogenize this mechanism.

2. The EnTech-model

A major drawback for practical policy analysis is that, up to now, endogenous growth models are mainly theoretical. This paper uses an empirical simulation model for technology policy which is inspired by some features of endogenous growth theory, but which is not an empirical counterpart of these theoretical models. Our model tries to intermediate between these formal endogenous growth models and the traditional macroeconomic models used in policy analysis in The Netherlands; these empirical models are usually specified in a rather *ad hoc* manner. At the core of our model is the production block, where investments in technology capital and in human capital play a major role. The external effects of R&D are modelled in such a way that R&D investments not only lead to more technology capital, but also have a positive impact on human capital through 'learning by doing' and 'learning by designing'.

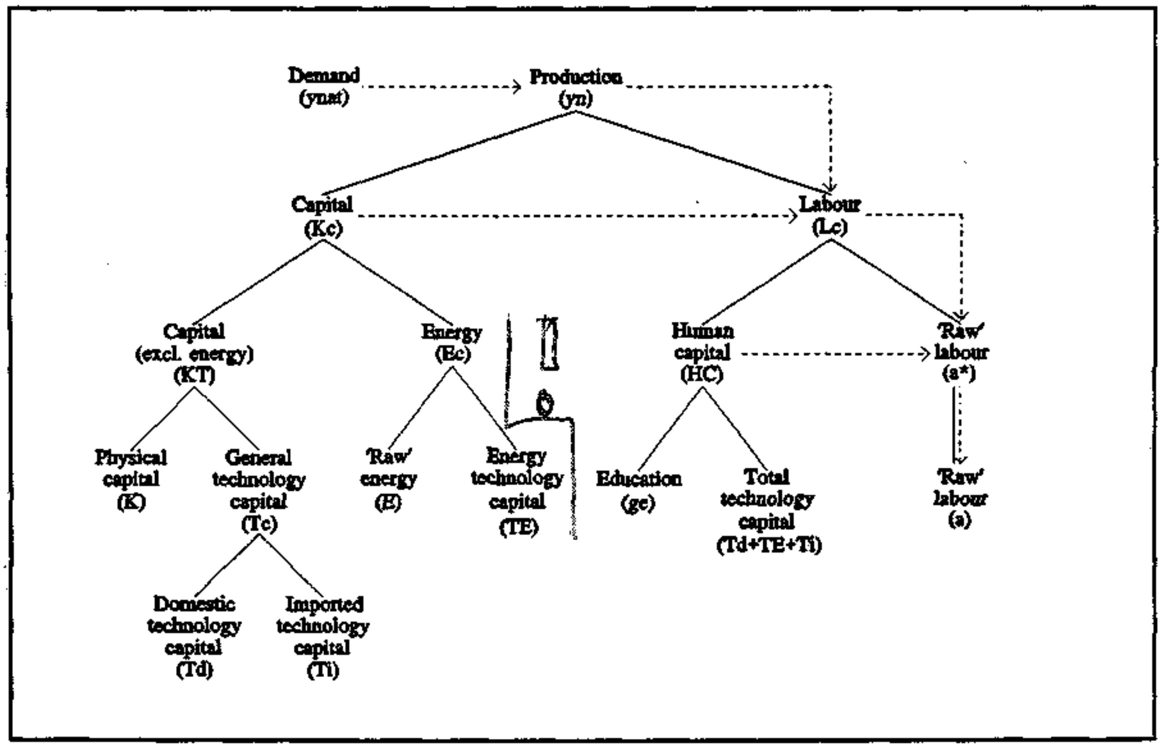
In order to capture the main characteristics of the structure of production and the role of technology capital in our simulation model, we use a framework of nested CES-functions, which allows for different elasticities of substitution between the various levels distinguished in the model. Whilst the manner in which the various production factors are combined in such a nested construction is rather *ad hoc*, its design is based on arguments and empirical evidence from the literature, and it is open to sensitivity analysis (see Den Butter and Wollmer, 1992, for more details). For a similar approach we refer to Gelauff *et al.* (1991).

Our simulation model takes the view that prices are rigid and that markets can be in disequilibrium for a prolongued period. In line with the traditional dynamic policy models for The Netherlands we assume that production is mainly demand determined. Therefore we derive the specification of the factor demand equations, which determine the factor inputs in the production block, from cost minimisation, given production (or productive capacity) and given the nested structure of the production block. Thus, the derived factor demand equations have total production as scaling variable and the relative prices of all production factors as other explanatory variables. In order to make the specification of the factor demand equations more realistic and in conformity with empirical specifications from the literature we have included lagged reactions and additional explanatory variables into the factor demand equations. In that case combined factor demand will, through the production block, no longer automatically yield desired production, so that we have to consider one production factor as residual in the model. Labour demand is taken as the residual factor demand, so that the effects of technology and the resulting spill-overs on labour demand are implicitly described by the model[3]. The advantage of our disequilibrium approach over a general equilibrium model is, that the model describes the historical time path of major economic variables and that we are able to simulate the effects of (policy) shocks on the short and medium term.

In this paper we only present a general outline of the model. For details we refer to the monograph of Den Butter and Wollmer (1992) which describes a previous version of the model. Appendix A gives a listing of the model equations. Appendix B provides a glossary of symbols used. Figure 1 shows the structure of the production block. At the highest level of nesting productive capacity, y_n, is a function of efficiency units of capital (including energy), K_c, and labour, L_c (A.1). L_c refers to efficiency units of labour, L, adjusted for changes in contractual working time (A.2). L is determined by the full capacity demand for labour, a^*, and the level of human capital, HC (A.3). K_c is determined by efficiency units of capital (excluding energy), K_T, combined with energy, also measured in efficiency units (E_c; (A.4)).

Technology capital, T_c and (T_d + T_E + T_i), enters into the production block in two related ways. Firstly, firms accumulate knowledge by either undertaking research and development, which provides a domestically produced stock of technical capital, T_d, or they import knowledge, and have a 'substitute' stock of foreign technical capital T_i. This technology capital is combined to T_c (A.8) which may be viewed as being embodied in capital, K, or disembodied and increasing the productivity of existing capital, or both, and thereby determines the level of *efficiency* units of capital, K_T (A.5). Moreover, in order to endogenize energy saving technology, this version of the model distinguishes between general technology capital and cumulated investments in energy saving technology which enhances the efficiency of the use of energy (T_E). Therefore, energy saving technology capital combined with input of 'raw' energy (E) yields efficiency units of energy (E_c; (A.10)).

Figure 1. Structure of production block



In line with recent theories of endogenous growth there is assumed to be spill-overs of knowledge associated with research and development and the import of technical capital. This is assumed to augment the human capital of workers as they work with the new technologies, *i.e.* through 'learning-by-doing' and 'learning-by-designing'. This augmentation of human capital combines, in a complementary manner, with the education level of workers, which is itself determined by real government expenditures on education, g_e[4] (A.12).

When all factor inputs (including labour supply) were given, y_n would be endogenously determined by the production block. Hence 'causality' would run from the lower elements in the tree of Figure 1 (indicated by solid lines) to the highest hierarchical level where y_n is the final variable to be determined. However, as mentioned before, our model has productive capacity fully demand determined and labour demand, a, to follow as a residual (A.13); in this case a positive investment impulse will, *ceteris paribus*, result in less labour demand, but a higher level of labour productivity. Then 'causality' runs from the left to the right in Figure 1 (indicated by broken lines) so that L_c and hence a result as final variables to be determined by the production structure. The model was calibrated on basis of this specification.

Although the calibration of the model is based on actual annual time series data, with reference period 1972-1990, we have deliberately not tried to estimate the full model using this data set.

The two major reasons are that the model contains a lot of unobservables and that the information contents of the data set is too poor to yield plausible parameter estimates in the behavioural equations of the model.
Instead, our calibration procedure uses a much wider set of information, namely information contained in the body of empirical knowledge. Moreover, when no empirical results are available from the literature, we include parameter estimates (or 'guesstimates') of our own. However, in those cases we do deliberately not present the usual set of test statistics, as our method of specifying the model makes this meaningless. Finally we note that in each behavioural equation the constant term is determined by least squares estimation.

As mentioned before, the factor demand equations of the production block are derived demand equations, based on cost minimization given the desired level of productive capacity y_n, and are extended in an ad hoc manner with adjustment lags and some additional explanatory variables suggested by the literature (see (A.15), (A.16) and (A.17)). The production block is calibrated in such a way that the (implicit) wage costs elasticity of labour demand amounts to about -0.5, which is in conformity with labour demand studies for The Netherlands. Government expenditure on education is exogenous to the model.

Although we try to keep the model as simple as possible, we needed some disaggregation of the energy block for the simulation exercises of this paper. The industrial use of energy (E) is modelled in the same manner as the other factor demand equations and depends on the price of energy, the prices of the other production factors and the volume of production as a scaling variable (A.24). In conformity with the international literature (see e.g. Seale jr. *et al*, 1991) we assume a long run price elasticity of -0.75 and a mean adjustment lag of 1 year. We note that the (absolute) value of this elasticity is rather high as compared to empirical findings for The Netherlands. The part of R&D-expenditures which are invested in energy saving technology depends on the relative price of energy in comparison with the price of R&D (A.19). Besides the industrial use of energy, the model also comprises an equation for the demand for energy by households. This energy consumption depends on the price of energy paid by households - with a long run price elasticity of -0.5 - and on disposable income (A.29).

The rest of the model is kept as simple as possible and its specification and calibration is derived from policy models in The Netherlands. Desired productive capacity is determined by aggregate demand, which gives the model a demand oriented character (A.37-A.46). In order to describe the quality competition with other industrialised countries, the import and export equations contain an indicator for the relative stand of technology (*riv*), which is endogeneous in the model (see (A.30), (A.29) and (A.32)). Hence, a relative increase in R&D expenditures in The Netherlands will, according to the model, enhance the volume of exports and lower the volume of imports, so that it fosters demand. Of course, part of this effect will also be achieved through price competition, which is modelled in the import and export equations in the usual manner.

Prices at the goods market are determined by a simple mark-up price equation adding up the various factor costs, which can be associated with monopolistic competition ((A.33) and (A.34)). Wages are determined by a wage curve equation derived from Graafland (1992) (A.37). This equation describes the wage negotiation process in the Dutch institutional setting. Finally the model contains a number of technical equations, which endogenize the government budget (A.44-A.53). Firstly, the financial deficit of the government is exogenous. Furthermore, the size of the wedge - i.e. the difference between gross labour costs and net wages - is determined endogenously to achieve *ex post* budget neutrality. All the additional revenues of the energy levy are redistributed to producers and/or consumers.

We note that our model of endogenous energy saving technical progress distinguishes between three sources of a decrease in the demand for energy in case of a levy which enhances the price 3 manieren of energy:

1. the income effect, when the energy levy leads to a decrease in demand and hence in economic activity;
2. substitution from energy to other factors of production;
3. more energy saving technology induced by the higher price of energy leading to, *ceteris paribus*, a lower demand for 'raw' energy.

Most studies on the effects of energy prices on energy demand take both latter sources together, which is a decrease in the energy intensitity of production.

3. Simulation results

The aim of our simulation exercises using the model is threefold. Firstly, and most importantly, they are meant to illustrate the working of our model and especially those mechanisms that are associated with endogenizing (the bias of) technical progress. Secondly, the simulations may provide some quantitative indication of the effects of regulating energy levies. In this respect our calculations should be considered with caution because we run only very simple simulations and our model contains a number of assumptions on which little empirical evidence is available. For that reason we also conduct a sensitivity analysis, showing which parameter values and assumptions are crucial in the policy simulations and should be given empirical attention. Thus, we come to the third and implied aim of our policy simulations: they provide a guideline for further research on this subject.

The impulse-response tables of this paper give the differences between the baseline projection (1986-90) and the projection from the impulse for certain variables of interest which are endogenous in the model and which are relevant in the discussion on the double dividend hypothesis.

3.1 The effects of an energy levy

In table 1 the results of an energy levy of 50% on the energy price, where the proceeds are used to lower the employers' contributions to social security payments, is given (employers' scenario). It appears that in the case of a general levy, i.e. a levy on the energy price of both consumers and producers, energy use decreases while employment increases. In the short run the effects are smaller then in the longer run. This is due to the fact that in the short run the production structure is fixed mainly with respect to the composite capital input so that industrial energy use cannot decrease much. Also the consumers need some time to adjust their energy use. In the longer run substitution possibilities between energy and labour are larger. However, this effect will be (afzwakken) mitigated by shrinking production (relative to the reference path) and consequently decreasing use of all factors of production. In the first year the production growth increases due to substitution by households from energy use to other goods. In subsequent years, however, this effect is dominated by a slowdown in production growth as a consequence of increasing costs of production and hence a deterioration of the international competitive position.

In the short run disposable income increases due to the decreasing tax burden on labour. As a matter of fact employees are able to shift part of the tax burden to employers. However, in the longer run labour taxes increase again due to decreasing proceeds from the energy levy and thus disposable income decreases. Total expenditure on R&D decreases in the long run as a consequence of the slowdown of production growth; however, expenditure on energy saving R&D increases.

concl.ie : Conluding, both energy use and unemployment are reduced at the expense of lower disposable income in the long run, especially of non-workers and a slowdown in production growth.

In the case of a levy on the energy price of households only, the effects on labour demand and energy use are much smaller. Production growth increases even in the long run, due to the fact that the producers do not face higher energy prices but do take advantage of the lower taxes on labour. Labour costs decrease relative to the reference path, and substitution takes place from energy, capital and technology (including energy saving technology) to labour.

All in all, the occurrence of an employment double dividend in our empirical model seems to be in accordance with the theoretical analysis of Bovenberg c.s. In the EnTech-model capital is largely fixed in the short run. Consequently it is possible to shift part of the burden from labour to capital. In the longer run this effect will die out; on the other hand, the existence of transfers and the fact that we do not impose income neutrality, still allows to shift part of the burden away from workers to non-workers. Furthermore, the substitution elasticities are such that labour and energy are rather good substitutes. Substitution to labour lowers the labour productivity which in turn puts a downward pressure on wages leading to additional substitution to labour. Finally, the effects on employment are enlarged because the model allows for endogenous decisions on technological progress. Higher energy prices induce a shift of technological progress from labour saving to energy saving technological progress.

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3.2 Alternative redistribution schemes

An alternative for redistribution of the proceeds of the energy levy to employers' contributions to social security is to lower the employees' contribution to social security (employees' scenario). In table 2 the results of this exercise are given. The effects do not differ very much from those of table 1. The most striking difference is that disposable income of both workers and non-workers, under a general levy, now increases even in the long run, although wage costs decrease and prices increase to a larger extent than in the previous exercise. This latter effect is dominated by the decrease in employees' contribution to social security, which is relatively large, since total proceeds are redistributed to the consumers, although they bear only part of the tax burden. Furthermore, higher disposable incomes boost consumption and hence production.

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The effects of a regulating energy levy with redistribution to employers, as shown in table 1, reveal that this scenario has a negative impact on total investments in technology. We can use part of the proceeds of the levy to compensate for this endogenous fall in R&D expenditures. Since total expenditures on R&D in the Netherlands are relatively small compared to the proceeds of the levy, only a minor part of the proceeds would be needed for this purpose. In table 3 the results of a regulating energy levy of 50% are given, where 98% of the proceeds are used to lower employers contributions to social security, while 2% of the proceeds of the levy are used for higher R&D expenditures. In fact this means that R&D expenditures are increased by about 6% in the first year.

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Now, under a general levy a double dividend still occurs, though slightly weaker than in the employers' scenario. Furthermore, disposable income of both workers and non-workers is

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higher than in the original specification. The enhanced R&D expenditures lead to higher spillovers to human capital, which results in a more efficient use of labour in the production process and consequently in a downward effect on the demand for labour. Ceteris paribus this leads to a higher labour productivity which has an upward pressure on the wages and hence on disposable income and consumption. Finally, higher consumption boosts production as the model is demand determined.

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In the case of a household levy, a double dividend no longer occurs under this redistribution scheme. Labour demand slightly decreases, while unemployment increases by 0.1 %-point. The negative effect on the demand for labour resulting from increased expenditures on R&D dominates the substitution effects to labour due to lower labour costs.

3.3 Sensitivity analysis

Obviously the results obtained in the previous sections depend upon the chosen parameter values of the model. In this section we will investigate how sensitive the outcomes are with respect to the values of some key parameters. By varying these parameter values we may also get more insight in the relative (empirical) importance of the various mechanisms at work in the model. The most important parameters in our simulation experiments are the substitution elasticities between on the one hand energy and on the other hand labour and capital and the price elasticity of energy use.

First we will look at the substitution possibilities between energy and capital. In our basic specification the (direct) substitution elasticity between energy and capital is set to 0.33. When this substitution elasticity is doubled it appears that the effect of a general energy levy of 50% on labour demand is, according to the 'employers' scenario', much smaller than in the basic version of the model. Now less substitution will take place from energy to labour in favour of substitution to capital and R&D. Consequently, expenditures on energy saving R&D increase.

The substition possibilities between energy and labour can be decreased by decreasing the elasticity of substitution between capital and labour. From table 4 we learn that a decrease of the latter elasticity from 0.8 to 0.5 results in a smaller increase in labour demand as less substitution to labour takes place.

As no decisive conclusion can be drawn from the empirical literature with respect to the substitution elasticity between labour and human capital, this parameter is an obvious candidate for sensitivity analysis. Lowering this elasticity from 1.25 to 0.8 does not alter the results much.

Note that the fact that an energy levy has only a minor impact on spill-overs may influence this result. The impact of the spill-overs is lowering the weight of the spill-overs in the CES-equation for human capital from two-third to one-third and lowering the weight of human capital in the CES-function for efficiency units of labour from 0.5 to 0.25. Now the effect of the energy levy on labour demand is smaller, since the influence of the fall in spill-overs on labour demand is less.

A lower price elasticity of industrial energy use mitigates, not surprisingly, the reduction in industrial energy use. Consequently less substitution takes place between energy and the other factors of production including labour. A higher price elasticity of household energy use increases household energy savings but has almost no (additional) effect on the production structure and hence on the boost in employment.

One of the major mechanisms of the model is the effect of the lower labour productivity on wage costs and hence on labour demand. To test for this mechanism table 4 gives the results of an alternative specification with a long term effect of labour productivity on wage costs of 0.75 in stead of 1.0. The table shows that only wage costs are affected significantly, which tempts one to conclude that factor substitution is mainly driven by higher energy prices and the wage cost reduction through the redistributed revenues of the tax and only to a minor extent by the second-order effect that lower labour productivity leads to a downward pressure on wages and hence boosts labour demand.

Apart from price- and substitution elasticities the scope of the levy plays an important role. So, finally, the effects of an international energy levy are studied. Since the EnTech-model is not designed for this purpose, this exercise is implemented in a rudimentary way by assuming that the effect of the energy levy on the import prices is proportional with the effect on domestic prices. It appears that the results do not differ very much from a national levy, where domestic prices only increase to a minor extent and hence the international competitive position does not deteriorate much.

4. Concluding remarks

In this paper we have tested the double dividend hypothesis using a relatively simple and aggregated empirical macro-economic model for the Netherlands, called the EnTech-model. The EnTech-model especially highlights the role of technological progress in production and endogenises the direction (bias) of technical progress.

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Simulation experiments with an energy levy of 50% learn that at least in the short and middle-long run a double dividend can occur. A decrease in the wedge between labour costs borne by the employer and the net income received by the employee induces substitution effects to labour. These effects are enhanced by substitution effects induced by a shift in the direction of technological progress from labour saving to energy saving technological progress. A general levy yields stronger effects than a levy on the energy use of households only. Under a general levy production may decrease, but on the other hand the positive effects on energy use and employment are also larger.

Exercises using the EnTech-model illustrate how the relative importance of the economic mechanisms, which are relevant in the discussions on the effects of energy levies, depends upon the size of the substitution elasticities between energy, labour, technology capital and physical capital. Inspired by modern endogenous growth theory, the specification of the production block pays special attention to the spill-overs from technology capital to human capital. These spill-overs, which represent the positive externalities of R&D investments, are important for the impact of an energy levy on employment. The negative income effect of the energy levy results in a decrease in economic activity and hence in a decrease in employment, while the substitution effect enhances labour demand. Furthermore, in the EnTech-model the fall in economic activity will lead to less investments in R&D, so that there are also less spill-overs to human capital and thus an upward pressure on labour demand. Therefore, the net effect on labour demand is ambiguous and more positive (or less negative) according to our model than according to a model which does not endogenise technical progress in such a manner. The fact that the relative increase in the energy price induced by the levy leads to a greater share of investments in energy saving R&D further complicates the picture. Yet, given the selected parameter values of the basic version of our model, the higher share of investments in energy saving R&D is not enough to offset the decrease in total R&D expenditures. Hence, investments in energy saving R&D also decrease due to the energy levy. Therefore, we advocate that (a small) part of the proceeds of the energy levy is used for additional investments in R&D expenditures, although this way of redistribution has a negative effect on employment as compared to other redistribution schemes.

However, these outcomes of the model largely hinge on our selection of the parameter values. When calibrating the model we have tried to use as much information as is available from the literature. Yet, more empirical information on the structure of production and especially on the size of the externalities of R&D expenditures is essential for a proper quantitative assessment of the effects of an energy levy on energy use and employment in case one believes (and we do) that the mechanisms modelled in this paper are of importance.

Tables

(werkgevers)

Table 1. A regulating energy levy of 50%: employers-scenario

		General levy			Household levy		
Year		1	3	5	1	3	5
Production	%	0.2	-0.4	-0.7	0.2	0.1	0.1
Price of production	%	1.0	1.1	0.8	0.0	-0.4	-0.8
Labour demand	1000 ly.	31.4	49.9	50.4	0.8	4.5	6.7
Unemployment	%-point	-0.5	-0.7	-0.7	-0.0	-0.1	-0.1
Wage costs	%	-1.1	-3.1	-4.6	-0.6	-1.3	-2.0
Disposable income workers	%	4.1	0.7	-0.3	2.4	1.0	0.8
Disposable income non-workers	%	2.7	-0.3	-1.1	1.9	0.7	0.6
Consumption	%	2.2	0.6	-0.7	1.4	0.8	0.5
Total energy use	%	-11.0	-19.6	-22.3	-5.0	-8.7	-9.7
Research and development	%	-0.0	-0.7	-1.4	-0.0	-0.2	-0.4
of which: energy saving R&D	%	*3.9*	*3.3*	*2.7*	*0.0*	*-0.1*	*-0.3*

(werknem.)

Table 2. A regulating energy levy of 50%: employees scenario

		General levy			Household levy		
Year		1	3	5	1	3	5
Production	%	0.5	-0.1	-0.4	0.4	0.3	0.3
Price of production	%	1.5	2.2	2.4	0.4	0.4	0.2
Labour demand	1000 ly.	30.0	49.4	46.6	0.1	4.8	5.3
Unemployment	%-point	-0.5	-0.7	-0.6	-0.0	-0.1	-0.1
Wage costs	%	-0.2	-0.9	-1.5	0.0	-0.0	-0.1
Disposable income workers	%	7.3	4.6	4.5	4.4	3.5	3.7
Disposable income non-workers	%	5.4	2.9	2.7	3.6	2.7	2.9
Consumption	%	4.2	3.6	2.8	2.6	2.7	2.6
Total energy use	%	-10.4	-18.1	-20.3	-4.6	-7.6	-8.2
Research and development	%	0.2	0.0	-0.2	0.1	0.3	0.3
of which: energy saving R&D	%	*4.1*	*4.0*	*3.8*	*0.1*	*0.3*	*0.4*

Table 3. A regulating energy levy of 50%: R&D-scenario

		General levy			Household levy		
Year		1	3	5	1	3	5
Production	%	0.2	-0.3	-0.4	0.2	0.2	0.4
Price of production	%	0.9	0.9	0.6	0.0	-0.5	-0.9
Labour demand	1000 ly.	25.8	36.0	32.3	-2.6	-3.9	-4.0
Unemployment	%-point	-0.4	-0.5	-0.4	0.0	0.1	0.1
Wage costs	%	-1.0	-2.7	-3.8	-0.5	-1.1	-1.5
Disposable income workers	%	4.1	0.8	0.1	2.4	1.1	1.1
Disposable income non-workers	%	2.8	0.0	-0.5	2.0	0.9	1.0
Consumption	%	2.3	0.8	-0.3	1.4	0.9	0.8
Total energy use	%	-11.0	-19.5	-22.1	-5.0	-8.6	-9.5
Research and development	%	6.0	9.8	12.7	3.7	6.3	8.3
of which: energy saving R&D	%	*10.1*	*14.2*	*17.4*	*3.7*	*6.4*	*8.4*

Table 4. Sensitivity analysis on a levy of 50%: employers scenario

Year 5	energy use (%)	energy R&D (%)	production (%)	labour demand (%)	wage costs (%)
General levy	*industrial*				
Original specification	-27.1	2.7	-0.7	5.8	-4.6
More subst. energy / capital	-26.7	4.1	-0.4	3.1	-3.7
Less subst. capital / labour	-26.4	4.1	-0.6	4.5	-4.2
Less subst. labour / human capital	-27.1	2.8	-0.7	5.4	-4.4
Less effect of spill-overs	-26.7	3.0	-0.5	3.8	-3.7
Lower price elast. industrial energy use	-19.5	2.9	-0.6	4.3	-4.0
Higher price elast. household energy use	-27.1	2.7	-0.8	5.6	-4.4
Less effect of labour productivity on wages	-26.5	3.0	-0.7	5.4	-3.5
International energy levy	-26.5	3.1	-0.4	6.4	-4.2
Household levy	*household*				
Original specification	-17.7	-0.3	0.1	0.8	-2.0
Higher price elast. household energy use	-25.5	-0.3	0.0	0.6	-1.8
Less effect of labour productivity on wages	-17.6	-0.2	0.1	0.7	-1.9

Notes

1. Most policy proposals consider an energy levy which is partly based on energy use and partly on the carbon contents of energy. In our simulation model we simply implement an energy levy as a rise in the price of energy.

2. Their study has been very influential in the decision of the Dutch government not to impose a general energy levy unilaterally, but to restrict the scope of the levy to the 'household' sector (including small enterprises in the sheltered sector).

3. Empirical specifications of demand for labour as a derived demand equation often include an autonomous time trend representing the effects of labour saving technical progress. Such labour demand specification would not concord with the set-up of our model.

4. We note that this modelling of spill-overs poses a problem for the formal derivation of the factor demand equations from cost minimisation, because it yields two different specifications for the factor demand equations for (cumulated) R&D. In our actual model specification the problem is circumvented by taking labour demand as the residual factor.

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Appendix A. EnTech model equations

Production

$$y_n=\left(\alpha_{yn}L_c^{-\rho_{yn}}+(1-\alpha_{yn})K_c^{-\rho_{yn}}\right)^{-1/\rho_{yn}},\ \alpha_{yn}=0.65;\ \rho_{yn}=0.25^{(*)},\text{ determines } L_c \tag{A.1}$$

$$L_c=\frac{L}{1+0.5(1-h)},\text{ determines } L \tag{A.2}$$

$$L=\left(\alpha_L a^{*-\rho_L}+(1-\alpha_L)HC^{-\rho_L}\right)^{-1/\rho_L},\ \alpha_L=0.5;\ \rho_L=-0.2,\text{ determines } a^* \tag{A.3}$$

$$K_c=\left(\alpha_{kc}K_T^{-\rho_{kc}}+(1-\alpha_{kc})E_c^{-\rho_{kc}}\right)^{-1/\rho_{kc}},\ \alpha_{kc}=0.9;\ \rho_{kc}=2 \tag{A.4}$$

$$K_T=\left(\alpha_{kt}K^{-\rho_{kt}}+(1-\alpha_{kt})T_c^{-\rho_{kt}}\right)^{-1/\rho_{kt}},\ \alpha_{kt}=0.5;\ \rho_{kt}=1 \tag{A.5}$$

$$K=i+(1-\delta_k)K_{-1},\ \delta_k=0.072 \tag{A.6}$$

$$T_c=\left(\alpha_{tc}T_d^{-\rho_{tc}}+(1-\alpha_{tc})T_i^{-\rho_{tc}}\right)^{-1/\rho_{tc}},\ \alpha_{tc}=0.8;\ \rho_{tc}=-0.5 \tag{A.7}$$

$$T_d=(1-\delta_T)T_{d,-1}+RD_d,\ \delta_T=0.15 \tag{A.8}$$

$$T_i=(1-\delta_T)T_{i,-1}+RD_i \tag{A.9}$$

$$E_c=\left(\alpha_{ee}E^{-\rho_{ee}}+(1-\alpha_{ee})T_E^{-\rho_{ee}}\right)^{-1/\rho_{ee}},\ \alpha_{ee}=0.9;\ \rho_{ee}=-0.2 \tag{A.10}$$

(*) The values of σ in the factor demand equations are Allen partial elasticities of substitution. The Allen partial elasticities in lower levels of the nested CES-structure (σ^A_{low}) are related to those in the next higher level (σ^A_{high}) by the following equality,

$$\sigma^A_{low}=\sigma^A_{high}+\frac{1}{S_{high}}(\sigma^D_{low}-\sigma^A_{high})$$

where S_{high} refers to the total share of the input in the higher level. The *direct* elasticities of substitution (σ^D_{low}) between the inputs in the CES-equations are determined, using the presented values of ρ, by

$$\sigma^D=\frac{1}{\rho+1}.$$

$$T_E=(1-\delta_T)T_{E,-1}+RD_E \tag{A.11}$$

$$HC=\left(\alpha_{hc}g_e^{-\rho_{hc}}+(1-\alpha_{hc})[T_d+T_i+T_E]^{-\rho_{hc}}\right)^{-1/\rho_{hc}},\ \alpha_{hc}=0.33;\ \rho_{hc}=4 \tag{A.12}$$

$$a^*=const+a+0.4(0.95-q_k)\text{, determines } a \tag{A.13}$$

$$a_g=\frac{y}{a} \tag{A.14}$$

Factor demand

$$\begin{aligned}\ln(i)=const&+0.2\ln(i_{-1})+0.8\ln(y)-0.05\ln(\frac{P_k}{P_y})+0.2\ln(q_k)\\&+0.8\,\sigma_{yn}S_L\ln(w)+0.8\,\sigma_{kt}S_{tc}\ln(P_{RD})+0.8\,\sigma_{kc}S_E\ln(P_E)\end{aligned} \tag{A.15}$$

$$\begin{aligned}\ln(RD_d)=const&+0.7\ln(RD_{d,-1})+0.3\ln(y)-0.1\ln(\frac{P_{RD}}{P_y})\\&+0.3\,\sigma_{yn}S_L\ln(w)+0.3\,\sigma_{kc}S_E\ln(P_E)+0.3\,\sigma_{kt}S_k\ln(P_k)\end{aligned} \tag{A.16}$$

$$\begin{aligned}\ln(RD_i)=const&+0.5\ln(y)-0.7\ln(\frac{P_{RD}}{P_y})+1.7\ln(techgap)\\&+\sigma_{yn}S_L\ln(w)+\sigma_{kc}S_E\ln(P_E)+\sigma_{kt}S_k\ln(P_k)\end{aligned} \tag{A.17}$$

$$\begin{aligned}\ln(E)=const&+0.5\ln(E_{-1})+0.5\ln(y)-0.375\ln(\frac{P_E}{P_y})\\&+0.5\,\sigma_{yn}S_L\ln(w)+0.5\,\sigma_{kt}S_{tc}\ln(P_{RD})+0.5\,\sigma_{kt}S_k\ln(P_k)\end{aligned} \tag{A.18}$$

$$\ln(\frac{RD_E}{RD_d})=const+0.1\ln(\frac{P_E}{P_{RD}}) \tag{A.19}$$

$$\ln(c_E)=const+0.5\ln(c_{E,-1})-0.25\ln(\frac{P_{CE}}{P_v})+0.25\ln(y_b) \tag{A.20}$$

Demand

$$y = const + 0.5 y_{nat} \qquad \text{(A.21)}$$

$$y_{nd} = \frac{1}{0.95} y \qquad \text{(A.22)}$$

$$y_n = y_{n,-1} + 0.4 (y_{nd,-1} - y_{n,-1}) \qquad \text{(A.23)}$$

$$q_k = \frac{y}{y_n} \qquad \text{(A.24)}$$

$$y_{nat} = c + c_E + i + i_{nrn} + i_d + g_{cau} + g_e + b - m + n \qquad \text{(A.25)}$$

$$n = 0.005 y_{nat} \qquad \text{(A.26)}$$

$$\ln(c) = const + 0.2 \ln(c_{-1}) + 0.64 \ln(y_b) - 0.3 \ln\left(\frac{r_{-1} + 100}{\dot{P}^{e}_{-1} + 100}\right) \qquad \text{(A.27)}$$

$$\ln(i_{nrn}) = const + 0.2 \ln(i_{nrn,-1}) + 0.8 \ln(y) - 0.2 \ln\left(\frac{P_k}{P_y}\right) \qquad \text{(A.28)}$$

$$\ln(b) = const + 0.5 \ln(b_{-1}) + 1.0 (\ln(m_w) - 0.5 \ln(m_{w,-1})) + 1.0 \ln\left(\frac{P_m}{P_v}\right) + 0.1 \ln(riv_{-2}) \qquad \text{(A.29)}$$

$$\begin{aligned} \ln(m) = const &+ 0.5 \ln(m_{-1}) + 1.0 (\ln(y) - 0.5 \ln(y_{-1})) - 0.375 \ln\left(\frac{P_m}{P_v}\right) \\ &+ 0.5 \ln(q_k) - 0.08 \ln(riv_{-2}) \end{aligned} \qquad \text{(A.30)}$$

$$m_q = \frac{m}{y_{nat}} \qquad \text{(A.31)}$$

$$\ln(riv) = \ln\left(\frac{T_c}{FT_c}\right) \qquad \text{(A.32)}$$

Prices

$$\begin{aligned}\ln(P_y) = {}& const + 0.5\ln(P_{y,-1}) + 0.5S_L\ln(w) - 0.2\ln(a_g) + 0.45\ln(1+\tau_{ind}) \\ & + 0.045\ln(q_k - 0.85) + 0.5S_E\ln(P_E) + 0.5S_k\ln(P_k) + 0.5S_{tc}\ln(P_{RD})\end{aligned} \tag{A.33}$$

$$\ln(P_v) = \left[\frac{1}{1+m_q}\right]\ln(P_y) + \left[\frac{m_q}{1+m_q}\right]\ln(P_m) \tag{A.34}$$

$$\dot{P} = 100\,\frac{P_y - P_{y,-1}}{P_{y,-1}} \tag{A.35}$$

$$\dot{P}^{e} = \dot{P}_{-1} \tag{A.36}$$

$$\begin{aligned}\ln(w) = {}& const + 0.8\ln(w_{-1}) + 0.2\ln(P_v) + 0.1\ln(\frac{P_y}{P_v}) - 0.56(1 - q_L) \\ & + 0.2\ln(a_g) + 0.064\ln(RR) + 0.05\ln(1+\tau_a) + 0.17\ln(1+\tau_q)\end{aligned} \tag{A.37}$$

$$w_r = \frac{w}{P_v(1+\tau_q)} \tag{A.38}$$

$$P_k = P_{i,-1}\left[\frac{r}{100} - \frac{P_i - P_{i,-1}}{P_{i,-1}}\right] + \delta_k P_i \tag{A.39}$$

$$P_i = 0.35P_v + 0.65P_{v,-1} \tag{A.40}$$

$$r = const + 0.15\dot{P}^{e} + 0.15r_k + 0.7r_{bu} - 0.1\dot{e}^{e} \tag{A.41}$$

$$\dot{e}^{e} = \dot{e}_{-1} \tag{A.42}$$

$$P_{RD} = const + 0.4P_{RD,-1} + 0.4w \tag{A.43}$$

Government

$$g_{uit} = w_{ui} a_{ui} + w_{aow} a_{aow} \tag{A.44}$$

$$a_{ui} = \frac{U}{\pi} \tag{A.45}$$

$$\dot{w}_{ui} = \alpha_2 \{ \frac{\dot{w}(1 - \tau_a)}{(1 + \tau_q)} \} \tag{A.46}$$

$$\dot{w}_{aow} = \alpha_3 \{ \frac{\dot{w}(1 - \tau_a)}{(1 + \tau_q)} \} \tag{A.47}$$

$$g_{sal} = w_{gov} a_{gov} \tag{A.48}$$

$$\dot{w}_{gov} = \alpha_1 \{ \frac{\dot{w}}{1 + \tau_q} \} \tag{A.49}$$

$$t_{ind} = \tau_{ind} y_{nat} \tag{A.50}$$

$$t_{dir} = g_{sal} + g_{uit} + g_{aut} + g_e - t_{ind} - t_{aut} - fd_g \tag{A.51}$$

$$wedge = \frac{t_{dir} P_v}{w(a + a_{aut})} \tag{A.52}$$

$$\tau_a = wedge - \tau_q \tag{A.53}$$

$$y_b = (1 - \tau_a) w_r (a + a_{aut}) + w_{gov} a_{gov} + w_{ui} a_{ui} + w_{aow} a_{aow} \tag{A.54}$$

$$\ln(a_a) = const + 0.5 \ln(a_{a,-1}) + 0.5 \ln(a_{wa}) + 0.15 \ln(q_L) \tag{A.55}$$

$$U = a_a - a - a_{gov} - a_{aut} \tag{A.56}$$

$$q_L = 1 - \frac{U}{a_a} \tag{A.57}$$

Appendix B. Glossary of symbols

Variable	Definition
a	industrial employment
a^*	full capacity demand for labour
a_a	labour supply
a_{aow}	number of people receiving old age and survivors' benefits (AOW/AWW)
a_{aut}	non-manufacturing demand for labour (autonomous)
a_t	industrial labour productivity
a_{gov}	governmental demand for labour (number of civil servants)
a_{ui}	number of people receiving benefits excl. AOW/AWW
a_{wa}	working age population
b	volume of exports[*]
c	volume of consumption excl. household energy use
c_E	volume of household energy use
$\dot{e}^e$	expected change in exchange rate
E	volume of industrial energy use
E_e	efficiency units of industrial energy use
fd_g	volume of governmental deficit
FT_c	foreign technology capital
g_e	volume of government expenditure on education
g_{ex}	volume of other government expenditures (autonomous)
g_{sal}	volume of (net) governmental expenditures on wages
g_{uit}	volume of expenditures on benefits
h	contractual working time
HC	human capital
i	volume of (gross) fixed investment in industry
i_d	volume of investment in dwellings

(*) All volumes are in constant prices of 1980.

Variable	Definition
i_{nm}	volume of non-manufacturing investment (excl. dwellings)
K	volume of (physical) capital stock
K_c	efficiency units of capital incl. energy
K_T	efficiency units of capital excl. energy
L	efficiency units of labour
L_c	efficiency units of labour, corrected for contractual working time
m	volume of imports
m_q	ratio of imports to national income
m_w	index of world trade
n	volume of stockbuilding
π	share of unemployed in total number of people receiving benefits
$\dot{p}$	rate of inflation (refers to industrial output price)
$\dot{p}^e$	expected rate of inflation
P_{CE}	aggregated household price of energy
P_E	aggregated industrial price of energy
P_i	price index of investment goods
P_k	rental price of capital services
P_m	price index of imports
P_{RD}	price index of R&D
P_v	expenditure price index
P_y	price of industrial output
q_k	rate of capacity utilization
q_L	utilisation rate of labour
r	long term interest rate
r_{bu}	long term foreign interest rate
RD_d	volume of domestic expenditures on R&D, excl. energy saving R&D
RD_E	volume of domestic expenditures on energy saving R&D
RD_i	volume of import of knowledge (licences)
riv	relative innovative power

Variable	Definition
r_k	short term interest rate ('money market rate')
RR	replacement ratio
τ	indirect tax burden
t_a	direct tax burden for employees
t_{aut}	other tax revenues (autonomous)
T_c	total stock of technology capital, excl. energy saving technology capital
T_d	domestic stock of technology capital, excl. energy saving technology capital
t_{dir}	direct tax revenues
T_E	stock of energy saving technology capital
$techgap$	index of technology gap
T_I	stock of imported technology capital
t_{ind}	indirect tax revenues
t_q	direct tax burden for employers
U	unemployment
w	nominal gross wages in industry
w_{aow}	real net benefit rate AOW/AWW
$wedge$	nominal wedge between gross and net wages
w_{gov}	real net wages of civil servants
w_r	real gross wages in industry
w_{ud}	real net benefit level non-AOW/AWW
y	volume of manufacturing output / actual demand
y_b	volume of total disposable income
y_n	productive capacity in industry
y_{nat}	volume of gross national product
y_{nd}	desired productive capacity in industry

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