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Kurt Kratena, Mark Sommer *

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Key words: New Keynesian model, labour market policy, fiscal devaluation

JEL Code: C54, H23, J68.

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Introduction

The economic situation of the European periphery countries (Greece, Ireland, Portugal and Spain) in the aftermath of the Great Recession 2009 and the turmoil on European financial markets for public debt is characterized by high public and private (household) debt and high unemployment rates. Austerity policies have been introduced in these countries in order to reduce public deficits and the public debt burden. The experience of several years of missing these targets for public debt reduction has in turn opened a discussion on the correct estimation of fiscal multipliers. The body of literature on this issue has been growing very fast and has dealt with several macroeconomic aspects that are relevant for the magnitude of fiscal multipliers, see Illing and Watzka (2014) for a recent example. In model simulations In't Veld, J., (2013) has shown that the inter-regional spillover effects of simultaneous austerity policies among all European member states might be significant. The debate is not closed, but there is also some evidence that though fiscal multipliers are not constant and might be condiderably larger in times of financial crisis (Müller, 2014), austerity policy might not necessarily be self defeating, i.e. missing its own targets due to macroeconomic feedback effects.

On the other hand, as Blanchard, et al. (2013) have shown, in the aftermath of the Great Recession job creation might stay relatively low for some period, leading to sustained high unemployment rates accompanied by social problems. Therefore the question about policy options for lowering unemployment and fostering GDP growth, given the public debt and deficit constraints, arises. This is also the main issue of this paper, exemplified for the case of the Spanish economy. These policy options can be discussed from the perspective of their short-term contribution to alleviating the post-crisis economic and social problems, but at the same time also from their compatibility with mid-term strategic targets of European social and environmental policy. Ideally, improving the labour market and economic situation in the short-run, would not be counterproductive for achieving the mid-term targets.

This paper deals with two main policy options that can be implemented without violating the public debt-targets: (i) active labour market policies, and (ii) environmental fiscal devaluation. The latter has been intensively discussed for countries that have serious public budget constraints, see Farhi, et al. (2014) and De Mooji and Keen (2012), among others.

Fiscal devaluation can be seen as a special version of internal devaluation, where the decrease in wage costs and the increase in competitiveness are achieved by a shift in taxation from labour to consumption. The impact on domestic prices in foreign currency of this taxation shift is similar to the impact of currency devaluation. Farhi, et al. (2014) have shown how this positive impact on the domestic economy depends on feedback effects from the labour market, especially wage setting. For Spain, Alvarez-Martinez and Polo (2014) have also analysed other potential tax increases to balance the decrease in labour taxation, like income taxation and a decrease in the unemployment benefit rate. The latter is thought to counteract labour fraud and the shadow economy. Simulations of green taxation for Spain (Markandya, et al., 2013) have shown that assumptions about the magnitude and the reaction of the shadow economy play an important role in quantifying the welfare effect of tax reforms. The study by CPB (2013) shows for several European countries the results of model simulation based on macroeconomic models for normalized fiscal devaluations. In general, fiscal devaluation is well researched in a theoretical context or in macroeconomic model simulations. The model simulations presented here build on that work and add important industry details and combine environmental and competitiveness considerations.

The paper is organized as follows. The first section describes the main blocks of the model: household behavior and private consumption, firm behavior and production structure, the labour market, and the government sector including model closure. In the second section the data bases used, the main econometric estimation results for a panel of EU countries and the calibration methodology of the model for the Spanish economy are described. Finally, the third section contains the design and the results of the policy simulations with the model. The first simulation describes the impact of active labour market policies for Spain, where hiring subsidies for unemployed workers are used to match these unemployed persons with green jobs in recycling activities and refurbishing of buildings. This measure is accompanied by a shortening of the working time, where part of the income loss is compensated by public transfers, similar to the German "Kurzarbeit" sheme. Besides the labour market impact, these policies also have an impact on direct and indirect energy use of households and therefore on GHG emissions. The other simulation describes the results of 'environmental fiscal devaluation'. This fiscal devaluation is designed as a consumption tax on embodied GHG emissions in each commodity (according to the the 59 industry classification) with tax rates according to the EU Low Carbon Roadmap 2050 (European Commission, 2011) which is compensated by lower social security contributions by both employers and employees. The main idea behind this tax reform is combining potential short-run positive impacts on employment with long-run environmental targets. A crucial issue for this type of environmental fiscal devaluation is competitiveness: the consumption tax reduces internal demand and does not harm (price) competitiveness of the domestic industry like a general tax on GHG emissions (including production). Additionally, this consumption GHG emission tax does not lead to carbon leakage, as imported embodied emissions are levied in equal magnitude as domestic embodied emissions.

1. The model

The model approach applied can be characterized as a DYNK (DYnamic New Keynesian) model with rigidities and institutional frictions. In that aspect, the DYNK model bears some similarities with the DSGE (Dynamic Stochastic General Equilibrium) approach which has been intensively used recently in the analysis of labour market policy (Busl and Seymen, 2013 and Faia, et al., 2012). The model explicitly describes an adjustment path towards a long-run equilibrium. This feature of dynamic adjustment towards equilibrium is most developed in the consumption block and in the macroeconomic closure via a fixed short and long-term path for the public deficit. The term 'New Keynesian' refers to the existence of a log-run full employment equilibrium, which will not be reached in the short run, due to institutional rigidities. These rigidities include liquidity constraints for consumers (deviation from the permanent income hypothesis), wage bargaining (deviation from the competitive labour market) and an imperfect capital market. Depending on the magnitude of the distance to the long-run equilibrium, the reaction of macroeconomic aggregates to policy shocks can differ substantially.

The model describes the inter-linkages between 59 industries as well as the consumption of five household income groups by 47 consumption categories. The model is closed by endogenizing parts of public expenditure in order to meet the mid-term stability program for public finances in Spain.

1.1 Household behaviour and private consumption

The consumption decision of households in the DYNK model is modeled along the lines of the 'buffer stock model' of consumption (Carroll, 1997), including consumption of durables and nondurables (Luengo-Prado, 2006).

Durable demand and total nondurables

Consumers maximize the present discounted value of expected utility from consumption of nondurable commodity and from the service provided by the stocks of durable commodity:

$$\max_{(C_t,K_t)} V = E_0\left\{\sum_{t=0}^{\infty}\beta^t U(C_t,K_t)\right\} \tag{1}$$

Specifying a CRRA utility function yields:

$$U(C_t,K_t)=\frac{C_t^{1-\rho}}{1-\rho}+\varphi\frac{K_t^{1-\rho}}{1-\rho} \tag{2}$$

where φ is a preference parameter and $\rho > 0$ implies risk aversion of consumers.

The budget constraint in this model without adjustment costs for the durables stock is given by the definition of assets, A_t:

$$A_t=(1+r)(1-t_r)A_{t-1}+YD_t-C_t-(K_t-(1-\delta)K_{t-1}) \tag{3}$$

In (3) the sum of C_t and $(K_t-(1-\delta)K_{t-1})$ represents total consumption, i.e. the sum of nondurable and durable expenditure (with depreciation rate of the durable stock, δ). The gross profit income rA_{t-1} is taxed with tax rate t_r. These taxes therefore reduce the flow of net lending of households that accumulates to future assets. Disposable household income excluding profit income, YD_t, is given as the balance of net wages $(1-t_S-t_Y)w_tH_t$ and net operating surplus accruing to households $(1-t_Y)\Pi_{h,t}$, plus unemployment benefits transfers with UN_t as unemployed persons and br as the benefit replacement rate, measured in terms of the after tax wage rate, plus other transfers Tr_t:

$$YD_t=(1-t_S-t_Y)w_tH_t+(1-t_Y)\Pi_{h,t}+brw_t(1-t_S-t_Y)UN_t+Tr_t \tag{4}$$

The following taxes are charged on household income: social security contributions with tax rate t_S, which can be further decomposed into an employee and an employer's tax rate (t_{wL} and t_L) and income taxes with tax rate t_Y. The wage rate w_t is the wage per hour and H_t are total hours demanded by firms. Wage bargaining between firms and unions takes place over the employee's gross wage, i.e. w_t (1 - t_L).

Financial assets of households are built up by saving after durable purchasing has been financed, and the constraint for lending is:

$$A_t + (1-\theta)K_t \geq 0 \qquad (5)$$

This term represents voluntary equity holding, $Q_{t+1} = A_t + (1 - \theta)K_t$, as the equivalent of the other part of the durable stock (θK_t) needs to be held as equity. The consideration of the collateralized constraint is operationalized in a down payment requirement parameter θ, which represents the fraction of durables purchases that a household is not allowed to finance. One main variable in the buffer stock-model of consumption is 'cash on hand', X_t, measuring the household's total resources:

$$X_t = (1 + r_t)(1 - t_r)A_{t-1} + (1 - \delta)K_{t-1} + YD_t \qquad (6)$$

Total consumption is then defined as:

$$CP_t = C_t + K_t - (1 - \delta)K_{t-1} = r_t(1 - t_r)A_{t-1} + YD_t - (A_{t-1} - A_t) \qquad (7)$$

In (7) the last term represents net lending, so total consumption is the sum of durable and nondurable consumption or the difference between disposable income and net lending.

The model solution works via deriving the first order conditions for $\frac{\partial U_t}{\partial C_t}$ and $\frac{\partial U_t}{\partial K_t}$ taking into account $\frac{\partial C_t}{\partial K_t}$. Luengo-Prado (2006) arrives at an intra-temporal equilibrium relationship between C_t and K_t (mostly following Chah, et al., 1995) as one solution of the model, where the constraint is not binding, or (which is equivalent) the down payment share θ equals the user costs $\frac{r+\delta}{1+r}$. For all other cases, where the collateral constraint is binding, Luengo-Prado (2006) has shown that this relationship can be used to derive policy functions for C_t and K_t and formulate both as functions of the difference between cash on hand and the equity that the consumer wants to hold in the next period. A non-linear consumption function for durables, similar to the function described in Luengo-Prado and Sørensen (2004) for nondurables, is asuumed, stating that consumers seek for an equilibrium relationship of durables per household, h. Therefore, with higher levels of durables per households, the marginal propensity of investment in durables, C_{Kt} with respect to X_t decreases ($\beta_{K,4} < 0$) according to:

$$\begin{aligned}&\log C_{dur,t} = \beta_K + \beta_{K,1}\log X_t + \beta_{K,2}\theta_{Ct} + \beta_{K,3}\log\left(p_{dur,t}(r_t+\delta)\right)\\&+\beta_{K,4}\log X_t \log\left(K_{t-1}/h_{t-1}\right)\end{aligned} \tag{8}$$

Note that $C_{dur,t}$ is equal to K_t - (1 - δ)K_{t-1} in equation (7). The down payemt parameter θ in Luengo-Prado (2006) represents a long-term constraint between the liabilities stock and the durable stock of households that is imposed on financial markets and might change over time. Changes in this constraint on stocks can only be achieved in the long-term by imposing limits to the down payment for durable purchases, θ_{Ct}.

Equation (8) can be seen as the long-run relationship between $C_{dur,t}$ and X_t. The long-run marginal propensity of durable demand to cash on hand depends on the accumulated stock K_t/h_t and is defined by: $\beta_{K,1} + \beta_{K,4}\log\left(K_{t-1}/h_{t-1}\right)$. In the long-run, with rising income, households do not keep the relationship between durables and income constant, but the relationship between voluntary equity holding and income. That corresponds to the long-run solution of the buffer stock model without durables, where all equity accumulation is voluntary, because no collateral constraint is active. Usually, in the buffer stock model, non-stationarity of consumption, income and wealth is dealt with by normalizing the variables by dividing through permanent income. In this paper, instead, the non-stationarity is taken into account by formulating adjustment processes of short-term behavior towards long-run optimal relationships. Therrefore, demand for durables is formulated as an error correction mechanism (ECM), like in Caballero, 1993 and Eberly, 1994:

$$d\log C_{dur,t} = \gamma_K + \gamma_{K,1}\log d\log X_t + \gamma_{K,ECM}\begin{bmatrix}\log C_{dur,t-1} - \beta_K + \beta_{K,1}\log X_{t-1} + \beta_{K,2}\theta_{C,t-1} + \\ \beta_{K,3}\log\left(p_{dur,t-1}(r_{t-1}+\delta)\right) + \beta_{K,4}\log X_{t-1}\log\left(K_{t-2}/h_{t-2}\right)\end{bmatrix} \tag{9}$$

In (9) β_K and γ_K are constants (in the panel data regression cross section fixed effects), and $\gamma_{K,ECM}$ represents the ECM parameter with $\gamma_{K,ECM} < 0$. Equation (9) is specified for own houses (dwelling investment) and for vehicles ($C_{hous,t}$ and $C_{veh,t}$). The capital stock for both durables categories ($K_{hous,t}$ and $K_{veh,t}$) accumulates according to the following equation: $K_t = K_{t-1}(1-\delta) + C_{dur,t}$ starting from an estimated initial durable stock in t = 0. The depreciation rates (δ) are specific for both durable categories. Durable consumption is in equation (7) described as an investment (K_t - (1 - δ)K_{t-1}), which is the case for one of the two durable categories, namely expenditure for vehicle purchases. For own houses the consumption data do not contain dwelling investment for own houses, but imputed rents. This is due to the concepts in national accounting, which treat housing different from other durables. The imputed rents are calculated as a simple static user cost: $C_{rent,t} = p_{dur,t}(r_t + \delta)K_t$.

The demand function for total nondurable consumption is modeled with a positive marginal propensity of nondurable consumption to 'cash on hand' and a negative marginal propensity of total nondurable consumption to the product of the down payment (in percentage of durables) and durable demand:

$$\log C_t = \beta_C + \beta_{C,1} \log X_t + \beta_{C,2}\theta_{Ct} \log C_{dur,t} \tag{10}$$

This function takes into account that households need to finance the sum of $C_t + \theta_{Ct} C_{dur,t}$, but down payments will not be fully financed by savings in the same period and consumers smooth nondurable consumption accordingly. This smoothing is measured in (10) by the parameter $\beta_{C,2}$.

The long-run marginal propensity of nondurable demand to cash on hand is given by the direct impact ($\beta_{C,1}$) plus the indirect impact via $\theta_{Ct}\log C_{dur,t}$. The latter again depends on $\beta_{K,1} + \beta_{K,4} \log(K_{t-1} / h_{t-1})$, so that the total marginal propensity of nondurable demand to cash on hand is defined by: $\beta_{C,1} + \theta_{Ct}\beta_{C,2}\beta_{K,1} + \theta_{Ct}\beta_{C,2}\beta_{K,4} \log(K_{t-1} / h_{t-1})$

The second term in this relationship measures the necessary increase in savings for down payments due to an increase in durable demand, induced by a marginal increase in cash on hand. The last term measures the impact of the non-linearity in the reaction of durables demand to cash on hand on savings (and on nondurable demand). Note that as durable demand reacts to the price of durables and nondurable demand is linked to durable demand in (10), there is also an implicit price elasticity for nondurables at work. Like in the case of durable demand, the error correction mechanism (ECM) representation of (10) is:

$$d\log C_t = \gamma_C + \gamma_{C,1} \log d \log X_t + \gamma_{C,ECM} \left[\log C_{t-1} - \beta_C + \beta_{C,1} \log X_{t-1} + \beta_{C,2}\theta_{C,t-1} \log C_{dur,t-1}\right] \tag{11}$$

Energy demand

The energy demand of households comprises fuel for transport, electricity and heating. These demands are part of total nondurable consumption and are modeled in single equations, therefore assuming separability from non-energy nondurable consumption. According to the literature on the rebound effect (e.g.: Khazzoom, 1989), the energy demand is modeled as (nominal) service demand and the service aspect is taken into account by dealing with service prices. The durable stock of households (vehicles, houses, appliances) embodies the efficiency of converting an energy flow into a service level $S = \eta_{ES} E$, where E is the energy demand for a certain fuel and S is the demand for a service inversely linked by the efficiency parameter (η_{ES}) of converting the corresponding fuel into a certain service. For a given conversion efficiency, a service price, p_S, (marginal cost of service) can be derived, which is a function of the energy price and the efficiency parameter. Any increase in efficiency leads to a decrease in the service price and thereby to an increase in service demand ('rebound effect').

$$p_S = \frac{p_E}{\eta_{ES}} \tag{12}$$

For transport demand of households we take substitution between public (CP_{pub}) and private transport (CP_{fuel}) into account. For this purpose, a price (pc_{tr}) of the aggregate transport demand, CP_{tr}, is constructed:

$$pc_{tr} = \exp\left[\frac{CP_{fuel}}{CP_{tr}} \log pc_{S,fuel} + \frac{CP_{pub}}{CP_{tr}} \log pc_{pub}\right] \tag{13}$$

The price for fuels, $pc_{S,fuel}$, is defined as a service price. Total transport demand of households depends on this aggregate price as well as on total nondurable expenditure in a log-linear specification, so that the price and expenditure elasticity can be derived directly from the parameters ($\beta_{tr,1}$ and $\beta_{tr,2}$) :

$$\log CP_{tr} = \mu_{tr} + \beta_{tr,1} \log pc_{tr} + \beta_{tr,2} \log C_t \tag{14}$$

In (14) μ_{tr} is a constant or a cross section fixed effect in the panel data model.

The demand for transport fuels is linked to the vehicle stock and depends on the service price of fuels as well as on the endowment of vehicles of the population. The latter term is important because the second car of the household usually is used less in terms of miles driven than the first.

$$\log\left(\frac{CP_{fuel,t}}{K_{veh,t}}\right) = \mu_{fuel} + \gamma_{fuel}\log\left(\frac{p_{fuel,t}}{\eta_{fuel,t}}\right) + \xi_{fuel}\log\left(\frac{K_{veh,t}}{h_t}\right) \tag{15}$$

In (15) μ_{fuel} again is a constant or a cross section fixed effect and γ_{fuel} is the price elasticity under the condition that there is a unitary elasticity of fuel demand to the vehicle stock. Once total transport demand of households and demand for fuels for transport are determined, public transport demand can be derived as a residual.

The equations for heating and electricity demand are analogous to equation (15) and have the following form:

$$\log\left(\frac{CP_{heat,t}}{K_{hous,t}}\right) = \mu_{heat} + \gamma_{heat}\log\left(\frac{p_{heat,t}}{\eta_{heat,t}}\right) + \xi_{heat}\log(dd_{heat}) \tag{16}$$

$$\log\left(\frac{CP_{el,t}}{K_{app,t}}\right) = \mu_{el} + \gamma_{el}\log\left(\frac{p_{el,t}}{\eta_{el,t}}\right) + \xi_{el}\log(dd_{heat}) \tag{17}$$

In both equations the variable heating degree days dd_{heat} is added. All equations also contain autoregressive terms that have been omitted in this presentation. The durable stocks used are the total housing stock ($K_{hous,t}$) and the appliance stock ($K_{app,t}$). The latter is accumulated from consumption of appliances, CP_{app}, which in turn is explained in a log linear specification like total transport demand:

$$\log CP_{app} = \mu_{app} + \beta_{app,1}\log pc_{app} + \beta_{app,2}\log C_t \tag{18}$$

Again, μ_{app} is a constant or a cross section fixed effect. The total housing stock ($K_{hous,t}$) contains the stock of own houses, which is explained above and the stock of houses that are rented by households. The latter is driven by population dynamics.

Nondurable (non-energy) demand

The non-energy demand of nondurables is treated in a demand system. The one applied in this DYNK model is the Almost Ideal Demand System (AIDS), starting from the cost function for $C(u, p_i)$, describing the expenditure function (for C) as a function of a given level of utility u and prices of consumer goods, p_i (see: Deaton and Muellbauer, 1980) . The AIDS model is represented by the well known budget share equations for the i nondurable goods in each period:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log\left(\frac{C}{P}\right) \quad ; \quad i = 1...n, 1...k \tag{18}$$

with price index, P_t, defined by $\log P_t = \alpha_0 + \sum_i \alpha_i \log p_{it} + 0.5 \sum_i \sum_j \gamma_{ij} \log p_{it} \log p_{jt}$, often approached by the Stone price index: $\log P_t^* = \sum_k w_{it} \log p_{it}$.

The expressions for expenditure (η_i) and compensated price elasticities (ε_{ij}^C) within the AIDS model for the quantity of each consumption category C_i can be written as (the details of the derivation can be found in Green, and Alston, 1990)[1]:

$$\eta_i = \frac{\partial \log C_i}{\partial \log C} = \frac{\beta_i}{w_i} + 1 \tag{19}$$

$$\varepsilon_{ij}^C = \frac{\partial \log C_i}{\partial \log p_j} = \frac{\gamma_{ij} - \beta_i w_j}{w_i} - \delta_{ij} + \varepsilon_i w_j \tag{20}$$

In (20) δ_{ij} is the Kronecker delta with $\delta_{ij} = 0$ for $i \neq j$ and $\delta_{ij} = 1$ for $i = j$.

The commodity classification $i = 1...n$ in this model comprises the n non-energy nondurables: (i) food, and beverages, tobacco, (ii) clothing, and footwear, (iii) furniture and household equipment, (iv) health, (v) communication, (vi) recreation and accomodation, (vii) financial services, and (viii) other commodities and services.

Total household demand

The household model described determines in three stages the demand for different categories of durables, energy demand and different categories of nondurables. The vector of non-energy nondurable consumption, $(\mathbf{c}_{\mathrm{NE}})$ as described above, is given by multiplying total non-energy nondurable expenditure C with the column vector of budget shares, **w** (all bold characters are vectors or matrices), as determined in (18):

$$(\mathbf{c}_{\mathrm{NE}}) = C\mathbf{w} \tag{21}$$

The total consumption vector of categories of consumption in National Accounts (according to the COICOP classification), $\mathbf{c}_{\mathrm{C}}$, is transformed into a consumption vector by commodities

[1] The derivation oft the budget share w_i with respect to log (C) and log (p_j) is given by β_i and $\gamma_{ij} - \beta_i$ (log(P)) respectively. Applying Shephard's Lemma and using the Stone price approximation, the elasticity formulae can then be derived.

of the input-output core in the DYNK model in purchaser prices, $\mathbf{c}_{\mathrm{pp}}$, by applying the bridge matrix, $\mathbf{B}_{\mathrm{C}}$:

$$\mathbf{c}_{\mathrm{pp}} = \mathbf{B}_{\mathrm{C}}\,\mathbf{c}_{\mathrm{C}}\,; \quad \mathbf{c}_{\mathrm{C}} = \quad \mathbf{c}_{\mathrm{NE}} = \begin{pmatrix} .. \\ \mathbf{c}_{\mathrm{i}} \\ .. \end{pmatrix} \;;\; \mathbf{c}_{\mathrm{E}} = \begin{pmatrix} .. \\ \mathbf{c}_{\mathrm{f}} \\ .. \end{pmatrix}; \qquad \mathbf{k} = \begin{pmatrix} .. \\ \mathbf{c}_{\mathrm{j}} \\ .. \end{pmatrix} \tag{22}$$

where $i = 1...n$, $f = 1...k$, and $j = 1...m$.

The bridge matrix links the vectors and has the dimension industries in NACE classification * consumption categories in COICOP classification. Multiplying the vector $\mathbf{c}_{\mathrm{C}}$ in equation (22) by the bridge matrix $\mathbf{B}_{\mathrm{C}}$ and by a diagonal matrix of import shares $\mathbf{C}^{\mathrm{m}}$ or by $\left[\mathbf{I} - \mathbf{C}^{\mathrm{m}}\right]$ with $\mathbf{I}$ as the identity matrix, yields the vector of imported consumption goods ($\mathbf{c}_{\mathrm{pp}}^{\mathrm{m}}$) and of consumption goods from domestic production ($\mathbf{c}_{\mathrm{pp}}^{\mathrm{d}}$) respectively, both in purchaser prices:

$$\mathbf{c}_{\mathrm{pp}}^{\mathrm{m}} = \hat{\mathbf{C}}^{\mathrm{m}}\mathbf{B}_{\mathrm{C}}\begin{pmatrix} \mathbf{c}_{\mathrm{NE}} \\ \mathbf{c}_{\mathrm{E}} \\ \mathbf{k} \end{pmatrix} \qquad \mathbf{c}_{\mathrm{pp}}^{\mathrm{d}} = \left[\mathbf{I} - \hat{\mathbf{C}}^{\mathrm{m}}\right]\mathbf{B}_{\mathrm{C}}\begin{pmatrix} \mathbf{c}_{\mathrm{NE}} \\ \mathbf{c}_{\mathrm{E}} \\ \mathbf{k} \end{pmatrix} \tag{23}$$

After this multiplication, in a first step, taxes less subsidies are subtracted in order to arrive at consumption vectors net of taxes, $\mathbf{c}_{\mathrm{N}}^{\mathrm{m}}$ and $\mathbf{c}_{\mathrm{N}}^{\mathrm{d}}$:

$$\mathbf{c}_{\mathrm{N}}^{\mathrm{m}} = \left[\mathbf{I} - \hat{\mathbf{T}}_{\mathbf{N}}\right]\mathbf{c}_{\mathrm{pp}}^{\mathrm{m}} \qquad \mathbf{c}_{\mathrm{N}}^{\mathrm{d}} = \left[\mathbf{I} - \hat{\mathbf{T}}_{\mathbf{N}}\right]\mathbf{c}_{\mathrm{pp}}^{\mathrm{d}} \tag{24}$$

In (24), $\hat{\mathbf{T}}_{\mathbf{N}}$ is a diagonal matrix of net tax rates (with identical tax rates on domestic and imported commodities), and total net taxes (taxes less subsidies) from consumption are therefore given by:

$$T_N = \hat{\mathbf{T}}_{\mathbf{N}}\left[\mathbf{c}_{\mathrm{pp}}^{\mathrm{m}} + \mathbf{c}_{\mathrm{pp}}^{\mathrm{d}}\right] \tag{25}$$

By subtracting trade and transport margins as well, we arrive at consumption vectors in basic prices that determine consumption demand by detailed commodity.

1.2 Firm behaviour and production structure

The production side in the DYNK model is analysed within the cost and factor demand function framework, i.e. the dual model, in a Translog specification. The representative producers in each industry all face a unit cost function with constant returns to scale that determines the output price (unit cost), for given input prices. The input quantities follow from the factor demand functions, once all prices are determined. The Translog specification chosen in the DYNK model comprises different components of technological change. Autonomous technical change can be found for all input factors (i.e. the factor biases) and also as the driver of TFP (total factor productivity), measured by a linear and a quadratic component.

Substitution in a K,L,E,M^m,M^d model

The Translog model is set up with inputs of capital (*K*), labor (*L*), energy (*E*), imported (M^m) and domestic non-energy materials (M^d), and their corresponding input prices p_K, p_L, p_E, p_{Mm} and p_{Md}. Applying Shepard's Lemma yields the cost share equations in the Translog case, which in turn are used to derive the quantities of factor demand for (*K*), (*L*), (*E*), (M^m) and (M^d). For this production system the input prices can be viewed as exogenous. One part of the input prices is determined at national or global factor markets, which applies to the prices of (*K*), (*L*), and (*E*). The price of labour is determined at the labour market via wage functions by industry (see below). The price of capital is formulated as a simple static user cost price index with the following components: (i) the price of investment by industry, (ii) the smoothed interest rate, and (iii) the fixed depreciation rate. The financial market and monetary policy are not described in detail in the DYNK model, therefore the interest rate is assumed as exogenous and is approximated by the smoothed benchmark interest rate. The depreciation rate by industry is fixed (see below for data sources) and the price of investment by industry is endogenously derived from the price system in the DYNK model. The price of energy carriers is assumed to be determined at world markets for energy and is therefore treated as exogenous. Each industry faces a unit cost function for the price (p_Q) of output *Q*, with constant returns to scale

$$\log p_Q = \alpha_0 + \sum_i \alpha_i \log(p_i) + \frac{1}{2}\sum_i \gamma_{ii}\left(\log(p_i)\right)^2 + \sum_{i,j}\gamma_{ij}\log(p_i)\log(p_j) + \alpha_t t + \frac{1}{2}\alpha_{tt}t^2 + \sum_i \rho_{ti} t\log(p_i) \tag{26}$$

, where p_Q is the output price (unit cost), p_i, p_j are the input prices for input quantities x_i, x_j, and t is the deterministic time trend. Note that equation (24) comprises different components of technological change. Autonomous technical change can be found for all input factors (i.e. the factor biases, ρ_{ti}). Another source of autonomous technical change that only influences unit costs is TFP, measured by α_t, and α_{tt}.

The Translog model is set up with inputs of capital (K), labor (L), energy (E), imported (M^m) and domestic non-energy materials (M^d), and their corresponding input prices p_K, p_L, p_E, p_{Mm} and p_{Md}. As is well known, Shepard's Lemma yields the cost share equations in the Translog case, which in this case of five inputs can be written as:

$$
\begin{aligned}
v_K &= \left[\alpha_K + \gamma_{KK}\log(p_K / p_{Md}) + \gamma_{KL}\log(p_L / p_{Md}) + \gamma_{KE}\log(p_E / p_{Md}) + \gamma_{KM}\log(p_{Mm} / p_{Md}) + \rho_{tK}t\right] \\
v_L &= \left[\alpha_L + \gamma_{LL}\log(p_L / p_{Md}) + \gamma_{KL}\log(p_K / p_{Md}) + \gamma_{LE}\log(p_E / p_{Md}) + \gamma_{LM}\log(p_{Mm} / p_{Md}) + \rho_{tL}t\right] \\
v_E &= \left[\alpha_E + \gamma_{EE}\log(p_E / p_{Md}) + \gamma_{KE}\log(p_K / p_{Md}) + \gamma_{LE}\log(p_L / p_{Md}) + \gamma_{EM}\log(p_{Mm} / p_{Md}) + \rho_{tE}t\right] \\
v_M &= \left[\alpha_M + \gamma_{MM}\log(p_{Mm} / p_{Md}) + \gamma_{KM}\log(p_K / p_{Md}) + \gamma_{LM}\log(p_L / p_{Md}) + \gamma_{EM}\log(p_E / p_{Md}) + \rho_{tM}t\right]
\end{aligned}
\tag{27}
$$

The homogeneity restriction for the price parameters $\sum_i \gamma_{ij} = 0$, $\sum_j \gamma_{ij} = 0$ has already been imposed in (27), so that the terms for the price of domestic intermediates p_{Md} have been omitted. In this model, labour and import demand react to changes in the prices of all inputs and changes in time due to the factor biases that can be labour saving or labour using, as well as import saving or import using. The immediate reaction to price changes is given by the own and cross price elasticities. These own- and cross- price elasticities for changes in input quantity x_i can be derived directly, or via the Allen elasticities of substitution (AES), and are given as:

$$\varepsilon_{ii} = \frac{\partial \log x_i}{\partial \log p_i} = \frac{v_i^2 - v_i + \gamma_{ii}}{v_i} \tag{28}$$

$$\varepsilon_{ij} = \frac{\partial \log x_i}{\partial \log p_j} = \frac{v_i v_j + \gamma_{ij}}{v_i} \tag{29}$$

Here, the v_i represent the factor shares in equation (27), and the γ_{ij} the cross-price parameters.

The deterministic trend t captures the two different sources of autonomous technological change that together influence factor demand, i.e. TFP and the factor bias. The total impact of t on factor x_i is given by:

$$\frac{d\log x_i}{dt} = \frac{\rho_{ti}}{v_i} + \alpha_t + \alpha_{tt} t \tag{30}$$

This impact therefore depends negatively on the share and on the level of technology, due to the term $\alpha_{tt}t$. The factor shares v_i in (27) can be directly used to derive factor demand (in nominal terms), once the output at current prices $p_Q Q$ is given. For given input prices p_L, p_E, p_{Mm} and p_{Md} this can be transformed into factor demand in real terms (hours worked or employees for L and physical energy units for E). A special treatment is applied to the capital input. This is due to the inherent difference between the *ex post* rate of return to K that is implicit in treating operating surplus as the residual in total output and the *ex ante* rate of return to K used for the specification of the price of K (user cost). In economic terms, that represents an imperfect capital market, which can be in disequilibrium (see: Jorgenson, et al., 2013) so that the adjustment of the *ex post* rate of return to K towards the *ex ante* rate of return to K takes time. This adjustment is specified as a simple ECM process in each industry:

$$d\log(p_{K,t}) = \alpha_K + \beta_K d\log\left[p_{CF,t}(r_t+\delta)\right] + \tau_K\left[\log(p_{K,t-1}) - \mu_K - \gamma_K\left[p_{CF,t-1}(r_{t-1}+\delta)\right]\right] \tag{31}$$

The adjustment towards equilibrium is guaranteed by $\tau_K < 0$, r is the smoothed (MA process) benchmark interest rate and δ is the industry specific depreciation rate. The price p_{CF} is the price of investment (capital formation) by industry and both α_K and μ_K are cross section fixed effects across countries. Once p_K is determined, the factor share for K in (27) can be used to determine K_{jt} by industry (j), which in turn determines investment by industry CF_j by inverting the capital accumulation equation:

$$CF_{j,t} = K_{j,t} - (1-\delta)K_{j,t-1} \tag{32}$$

Intermediate input demand and factor prices

The factors E, M^m, and M^d are aggregates of the use matrix from the supply and use table system, which is the framework of this DYNK model. The aggregate E comprises four energy industries/commodities, and M^m, M^d the other 55 non-energy industries/commodities (see the Appendix for the full 59 industry/commodity classification of the DYNK model).

In a second nest, the factor E is split up into aggregate categories of energy (coal, oil, gas, renewable, electricity/heat) in a Translog model. The unit cost function of this model determines the bundle price of energy, p_E, and the cost shares of the five aggregate energy types:

$$\log p_E = \alpha_0 + \sum_i \alpha_{E,i} \log(p_{E,i}) + \frac{1}{2}\sum_i \gamma_{E,ii} \left(\log(p_{E,i})\right)^2 + \sum_{i,j} \gamma_{E,ij} \log(p_i)\log(p_j) + \sum_i \rho_{tE,i} t \log(p_{E,i}) \tag{33}$$

$$v_{E,i} = \left[\alpha_{E,i} + \sum_{i,j} \gamma_{E,ij} \log(p_{E,i}) + \rho_{tE,i} t \right] \tag{34}$$

This set of energy categories is directly linked to the energy commodities/industries of the use table.

The domestic as well as the import matrix are converted into 'use structure matrices' $\mathbf{S}^{\mathrm{m}}_{\mathrm{NE}}$ and $\mathbf{S}^{\mathrm{d}}_{\mathrm{NE}}$ by dividing by the column sum of total domestic and imported non-energy intermediates, respectively. Intermediate inputs by commodity are determined by multiplying diagonal matrices of the factor shares in (27), $\hat{\mathbf{V}}_{\mathrm{D}}$ and $\hat{\mathbf{V}}_{\mathrm{M}}$ with the 'use structure matrices' and with the column vector of output in current prices. The full commodity balance is given by adding the column vector of domestic consumption (equation (24)), capital formation by domestic goods, and other domestic final demand (exports $\mathbf{ex}^{\mathrm{d}}$, changes in stocks $\mathbf{st}^{\mathrm{d}}$ and public consumption $\mathbf{cg}^{\mathrm{d}}$). The capital formation vector by domestic goods is derived by multiplying the vector of investment by industry $\mathbf{cf_j}$ (equation (32)) with the capital structure matrix for investment, derived from the capital formation matrix (investment by industry * investment by commodity) for domestic investment demand: $\mathbf{cf}^{\mathrm{d}} = \mathbf{B}^{\mathrm{d}}_{\mathrm{K}}\mathbf{cf}_{\mathrm{j}}$. The total investment structure matrix is made up of domestic and imported investment structures ($\mathbf{B}^{\mathrm{d}}_{\mathrm{K}}$ and $\mathbf{B}^{\mathrm{m}}_{\mathrm{K}}$) and has column sum of one like the private consumption bridge matrix.

The (column vector) of the domestic output of commodities in current prices, $\mathbf{p}^{\mathrm{D}}\mathbf{Q}^{\mathrm{D}}$, is transformed into the (column vector) of output in current prices, $\mathbf{p}_{\mathrm{Q}}\mathbf{Q}$, by applying the market shares matrix, $\mathbf{C}$ (industries * commodities) with column sum equal to one:

$$\mathbf{p}^{\mathrm{D}}\mathbf{Q}^{\mathrm{D}} = \left\lfloor \hat{\mathbf{V}}_{\mathrm{D}}\mathbf{S}^{\mathbf{d}}_{\mathbf{NE}} \right\rfloor \mathbf{p}_{\mathrm{Q}}\mathbf{Q} + \mathbf{c}^{\mathrm{d}} + \mathbf{cf}^{\mathrm{d}} + \mathbf{ex}^{\mathrm{d}} + \mathbf{st}^{\mathrm{d}} + \mathbf{cg}^{\mathrm{d}} \tag{35}$$

$$\mathbf{p}_{\mathrm{Q}}\mathbf{Q} = \mathbf{C}\mathbf{p}_{\mathrm{D}}\mathbf{Q}_{\mathrm{D}} \tag{36}$$

The final demand categories in (35), i.e. $\mathbf{c}^{\mathrm{d}}$, $\mathbf{cf}^{\mathrm{d}}$, $\mathbf{ex}^{\mathrm{d}}$, $\mathbf{st}^{\mathrm{d}}$ and $\mathbf{cg}^{\mathrm{d}}$ are all in current prices.

Factor prices are exogenous for the derivation of factor demand, but are endogenous in the system of supply and demand. Some factor prices are directly linked to the output prices p_Q which are determined in the same system. All user prices are the weighted sum of the domestic price p^d and the import price, p^m. The import price of commodity i in country s is given as the weighted sum of the commodity prices of the k sending countries ($p^{d,k}$)

$$p_{i,s}^{m} = \sum_{k=1}^{s-1} w_{mk,s} p^{d,k} \tag{37}$$

This is derived from an inter-regional input-output system from the WIOD database (see next section). This gives one domestic price per user for each commodity (i.e. no price differentiation for domestic goods) and different import prices per user for each commodity, given by the different country source structure of imports of the same commodity by user. Once this user specific prices for intermediate goods are given, the 'use structure matrices' ($\mathbf{S}_{\mathrm{NE}}^{\mathrm{m}}$ and $\mathbf{S}_{\mathrm{NE}}^{\mathrm{d}}$) can be applied in order to derive the price vectos $\mathbf{p}_{\mathrm{Mm}}$ and $\mathbf{p}_{\mathrm{Md}}$:

$$\mathbf{p}_{\mathrm{Mm}} = \mathbf{p}^{\mathrm{m}}\mathbf{S}_{\mathrm{NE}}^{\mathrm{m}} \qquad \mathbf{p}_{\mathrm{Md}} = \mathbf{p}^{\mathrm{d}}\mathbf{S}_{\mathrm{NE}}^{\mathrm{d}} \tag{38}$$

The price of capital is based on the user cost of capital: $u_K = p_{CF}(r+\delta)$ with p_{CF} as the price of investment goods an industry is buying, r as the deflated benchmark interest rate and δ as the aggregate depreciation rate of the capital stock K. The investment goods price p_{CF} can be defined as a function of the domestic commodity prices and import prices, given the input structures for investment, derived from the capital formation matrix described above for domestic and imported investment demand:

$$\mathbf{p}_{\mathrm{CF}} = \mathbf{p}^{\mathrm{m}}\mathbf{B}_{\mathrm{K}}^{\mathrm{m}} + \mathbf{p}^{\mathrm{d}}\mathbf{B}_{\mathrm{K}}^{\mathrm{d}} \tag{39}$$

It is important to note that by these input-output loops in the model, indirect effects or feedback effects of prices occur and factor demand reactions therefore differ from what the *ceteris paribus* price and substitution elasticities indicate. All user prices (for example the price of private consumption) can further be aggregated in order to derive the aggregate price index of the corresponding demand aggregate.

1.3 Labour market

The main factor market that has important repercussions in the case of policy simulations in the DYNK model is the labour market. In CGE modeling, different labour market approaches can be integrated (Boeters and Savard, 2013) and calibrated. In this exercise, the theoretical approaches need to be confronted with the results from empirical wage curve estimation, which can be seen as a robust empirical relationship (Card, 1995 and Blanchower and Oswald, 1994). The wage curves in the DYNK model are specified as the employee's gross wage rate per hour by industry, i.e. w_t (1 - t_L). The labour price (index) of the Translog model is then defined by adding the employers' social security contribution to that. Combining the *meta-analysis* of Folmer (2009) on the empirical wage curve literature with a basic wage bargaining model from Boeters and Savard (2013) gives a specification for the sectoral hourly wages. These functions describe the responsiveness of hourly wages to labour productivity (industry, aggregate), consumer prices, hours worked per employee, and the rate of unemployment. The inclusion of the variable ' hours worked per employee' corresponds to a bargaining model, where firms and workers (or unions) bargain over wages and hours worked simultaneously (Busl and Seymen, 2013). The basic idea is that the gains in labour productivity can be used for cutting hours worked and wage increases simultaneously. While unions formally bargain over an hourly wage rate, they also take annual (or monthly) wage income per head into account (for example for minimum wage considerations). We specify the wage function in a way that the hours can be determined in a first step and then the hourly wage rate is determined. A bargaining over hours that leads to less hours worked, would *ceteris paribus* lower annual wage income per head. Therefore unions, in consequence, bargain an increase in the hourly wage rate, so income per year does not fall in the proportional amount of working time reduction. This specification follows the assumption that the productivity increase is never fully compensated only by a reduction of working time, but split up into working time reduction and wage increase. The parameter estimated for labour productivity in the wage curve therefore is conditional on this impact of working time on hourly wages.

In the search model firms and workers bargain over the distribution of the value of a successful match and the wage rate can be derived from the optimality conditions of the problem (see: Boeters and Savard, 2013):

$$w = \frac{\left(1-t^m\right)\lambda\left(\rho + \frac{s}{ur}\right)}{\pi_V\left(1-br\right)\left(1-t^a\right)}\gamma \tag{40}$$

In (40) t^m and t^a represent marginal vs. average income tax rates, therefore, if we assume a proportional tax system for simplicity (and for the sake of data availability) this wage equation can be reduced to:

$$w = \frac{\lambda\left(\rho + \frac{s}{ur}\right)}{\pi_V\left(1-br\right)}\gamma \tag{41}$$

In this wage equation, λ is the parameter measuring the bargaining power of workers, ρ is the discount rate, s the (exogenous) separation rate, π_V the probability of filling a vacancy and ur the rate of unemployment. The cost of an open vacancy for the firm is measured by γ and br is the wage replacement rate of the unemployment benefit as defined in (4). The separation rate could be endogenized in the labour demand block and usually depends on workers productivity, like in Faia, et al. (2013). As Boeters and Savard (2013) point out, some of these variables are difficult to measure or derive from official data. One important property of the wage function is the reaction of the wage rate to the unemployment rate, which according to the empirical 'wage curve' literature is about -0.1. Taking these theoretical considerations as a starting point we derive the following log-linearized wage curve by industry:

$$\begin{aligned}\log w_{j,t}\left(1-t_{L,t}\right) &= \alpha_{w,j} + \sum_{t=t-n}^{t}\beta_{1,wj}\log pc_t + \sum_{t=t-n}^{t}\beta_{2,wj}\log(Q_{j,t}/H_{j,t}) + \\ &+ \sum_{t=t-n}^{t}\beta_{3,wj}\log(Q_t/H_t) + \sum_{t=t-n}^{t}\beta_{4,wj}\log(ur^*/ur_t) - \sum_{t=t-n}^{t}\beta_{5,wj}\log(H_{j,t}/L_{j,t})\end{aligned} \tag{42}$$

The specification in (42) takes into account different lags of variables, including the consumer price, and the industry (j) productivity or alternatively the aggregate productivity of the economy. The term ur^*/ur_t considers the unemployment elasticity of the wage rate in terms of the difference to the equilibrium rate ur^*, measured in that case as the minimum rate in the sample used for estimation. The estimation of the parameter $\beta_{4j,w}$ yields the same result (only with $\beta_{4j,w} > 0$) as the parameter of the unemployment rate elasticity in the traditional wage curve, because all the variance in the term ur^*/ur_t stems from changes in the unemployment rate. The specification of the unemployment term as a gap to full employment (ur^*/ur_t) yields a NAWRU characteristic: wage inflation increases with approximation to full employment. Due to non-stationarity of the variables, an autoregressive term is also included. The separation rate and the probability of filling a vacancy have not been included into (42) due to data availability and the income replacement rate of the unemployment benefit did not yield significant results in the panel data estimation across European countries. The stylized facts on the latter phenomenon reveal that there is no clear correlation between the generosity of the unemployment benefit regulation and the unemployment rate.

Labour supply is given by age and gender (g) specific participation rates of the k age groups of the population at working age (16-65) and evolves over time according to demographic change (age group composition) and logistic trends of the participation rates. Therefore, labour supply does not react endogenously to policy shocks. Unemployed persons are the difference between labour supply and employment, for given hours worked per person:

$$UN_t = \sum_{k,g} \pi_{k,g,t} pop_{k,g,t} - w_t H_t \left(\frac{L_t}{H_t} \frac{1}{w_t} \right) \tag{43}$$

Total wages are given in analogy to the other factor inputs (E, M^m, and M^d) by multiplying the diagonal matrix of the factor shares in (27), in that case $\hat{\mathbf{V}}_{\mathrm{L}}$, with the column vector of output in current prices and summing up (with $\mathbf{i'}$ as the summation vector): $w_t H_t = \mathbf{i'} \left\lfloor \hat{\mathbf{V}}_{\mathrm{D,t}} \mathbf{p}_{\mathrm{Q,t}} \mathbf{Q_t} \right\rfloor$.

1.4 Government and model closure

The public sector balances close the model and show the main interactions between households, firms and the general government. As we put special emphasis on labour market policies, unemployment benefits are separated from the other social expenditure categories. Taxes from households and firms are endogenized via tax rates and the path of the deficit per GDP share according to the EU stability programs is included as a restriction.

Wage income of households is taxed with social security contributions (tax rates t_{wL} and t_L) and wage income plus operating surplus accruing to households are taxed with income taxes (tax rate t_Y). Additionally, households' gross profit income is taxed with tax rate t_r. Taxes less subsidies are not only levied on private consumption as described in (25), but also on the other final demand components in purchaser prices ($\mathbf{f_{pp}}$, comprising capital formation, changes in stocks, exports, and public consumption) as well as on gross output. Total tax revenues of government, T_t, are given with:

$$T_t = (t_{wL} + t_L) w_t H_t + t_Y (w_t H_t + \Pi_{h,t}) + t_r r_t A_{t-1} + \hat{\mathbf{T}}_{\mathrm{N}} \left[\mathbf{c}_{\mathrm{pp,t}} + \mathbf{f}_{\mathrm{pp,t}} + \mathbf{p}_{\mathrm{Q,t}} \mathbf{Q_t} \right] \tag{44}$$

Taxes less subsidies and profit income in (44) also include the economic activity of the public sector itself. The expenditure side of government is made up of unemployment transfers ($brw_t(1 - t_S - t_Y)UN_t$) and other transfers to households (Tr), public investment (cf_{gov}) and public consumption (cg). Additionally, the government pays interest with interest rate r_{gov} on the stock of public debt, D_{gov}. The change in this public debt is equal to negative government net lending, which is then given by:

$$\begin{aligned} \Delta D_{gov,t} &= brw_t (1 - t_S - t_Y) UN_t + Tr_t + cf_{gov,t} + cg_t + r_{gov,t} D_{gov,t-1} - (t_{wL} + t_L) w_t H_t - t_Y (w_t H_t + \Pi_{h,t}) \\ &- t_r r_t A_{t-1} - \hat{\mathbf{T}}_{\mathrm{N}} \left[\mathbf{c}_{\mathrm{pp,t}} + \mathbf{f}_{\mathrm{pp,t}} + \mathbf{p}_{\mathrm{Q,t}} \mathbf{Q}_{\mathrm{t}} \right] \end{aligned} \tag{45}$$

In that specification, tax revenues and unemployment benefits are endogenous and can from a policy perspective be influenced by changing tax rates or the unemployment benefit replacement rate. The model is closed by further introducing a public budget constraint, specified via the stability program for public finances of Spain that defines the future path of government net lending to GDP ($p_y Y$). The latter can be defined as the difference between total output $p_Q Q$ and intermediate demand ($p_E E$, $p_{Mm} M^m$, $p_{Md} M^d$). Linking public investment with a fixed ratio (w_{cf}) to public consumption and introducing the net lending to GDP constraint, public consumption is then derived as the endogenous variable that closes the model:

$$\begin{aligned} cg(1 + w_{cf}) &= \Delta D_{gov,t} / p_y Y - r_{gov,t} D_{gov,t-1} - brw_t (1 - t_S - t_Y) UN_t - Tr + (t_{wL} + t_L) w_t H_t \\ &+ t_Y (w_t H_t + \Pi_{h,t}) + t_r r_t A_{t-1} + \hat{\mathbf{T}}_{\mathrm{N}} \left[\mathbf{c}_{\mathrm{pp,t}} + \mathbf{f}_{\mathrm{pp,t}} + \mathbf{p}_{\mathrm{Q,t}} \mathbf{Q}_{\mathrm{t}} \right] \end{aligned} \tag{46}$$

Therefore, transfers and tax rates are treated like fiscal policy variables, whereas public consumption and investment adjust according to the net lending to GDP constraint. Public investment can be still treated as a policy variable, as the public investment ratio (w_{cf}) could be altered.

2. Data, estimation and calibration

The data for the estimation of consumption demand functions are mainly taken from EUROSTAT's National Accounts. That comprises the expenditure data as well as all income components and asset data, which are part of cash on hand. The categories of durable consumption in our model comprise investment in own houses and purchases of vehicles. Due to the specific treatment of housing in the consumption accounts of national accounting, investment in own houses is pooled together with other dwelling investment to derive total dwelling investment. In a first step, a capital stock of housing property was estimated for one year, based on the Household Financial and Consumption Survey (HFCS) of the ECB. By applying property prices from the Bank of International Settlement (BIS) and EUROSTAT population data, a time series of own houses was constructed for those 14 EU countries where sectoral accounts (income, asset data) were available from 1995 to 2011. A more simple procedure could be applied to vehicles, as the expenditure data are available (C_{veh} in (47)) and no re-valuation of the existing stock needed to be taken into account there. For own houses, the dwelling investment (CF_{hous}) was calculated as implicit. Measuring all variables in current prices, the two capital stocks K_{veh} and K_{hous} in current prices accumulate according to the following equations:

$$K_{veh,t} = K_{veh,t-1}\left(1-\delta_{veh}\right)+C_{veh,t} \tag{47}$$

$$K_{hous,t} = \frac{p_{hous,t}}{p_{hous,t-1}}\left[K_{hous,t-1}\left(1-\delta_{hous,t}\right)+CF_{hous,t} / p_{CF,t}\right] \tag{48}$$

In (48) revaluation of the stock is driven by the yearly change in house prices. The price p_{hous} is the price of the housing stock and comprises increases in construction prices (p_{CF}) as well as changes in land prices. The variables C_{veh} and CF_{hous} add up to total gross capital formation by households, a variable that is also found in the sectoral accounts of households in National Accounts. Given the demand and the accumulated stock of own houses, imputed rents are calculated by applying a user cost formulation. These imputed rents enter the consumption accounts. The expenditure for imputed rents, vehicles and total nondurables adds up to total private consumption.The down payment for durable purchases, θ_{Ct} is calculated by relating the change in liabilities to the durable demands (C_{veh} and CF_{hous}), that gives (1 - θ_{Ct}). The original θ_t from Luengo-Prado (2006) is measured in this model by the relationship (1 – liabilities/durable stock) and can only be controlled by fixing certain values of θ_{Ct} and solving the model to derive the path of θ_t. In an iterative procedure dynamic convergence towards target values of θ_t can then be achieved.

The functions for the two durable demand categories and for total nondurables have been estimated with panel data econometrics for 14 EU countries (1995 - 2011), based on EUROSTAT and other sources. Non-linear relationships of durable consumption and 'cash on hand' have been identified from these estimations. Non-stationarity has not been considered by normalizing by permanent income as is usual in the calibrated versions of the buffer stock model, but by directly estimating an error correction mechanism (ECM) model. Table 1 shows the short- and long-run parameters for the two durable categories as well as for total nondurables. The small impact of $\theta_{Ct}\log(C_{dur,t})$, i.e. of the need to finance the down payment, is an indication that the consumer smoothes consumption and does not fully react to shocks in liquidity. The model has been calibrated for the income quintiles in Spain, based on income data from EU SILC and wealth data from the HFCS survey. Table 2 shows that in the base year only small differences can be found in the marginal propensity of consumption with respect to cash on hand.

The other more important property of the buffer stock model, however, is the reaction of consumption (growth) to lagged income growth (excess sensitivity), an empirical phenomenon first found by Hall (1978) and challenging the permanent income hypothesis. This is usually tested by an OLS regression of consumption growth on lagged income growth, including a constant. Luengo-Prado (2006) presents excess sensitivity results from US stylized macroeconomic facts and confronts these results with results from her calibrated model. The excess sensitivity coefficients found by Luengo-Prado (2006) are 0.16 (nondurables) and 0.26 (durables). For the DYNK model presented in this paper, excess sensitivity has been tested at the level of income quintiles and based on the baseline run of the model for Spain until 2050. Sensitivity analysis has been carried out for high and low θ, i.e. the long-run liquidity constraint between the durable stock and household debt. In the "low θ " case this ratio still increases slightly and then converges to a value that is considerably higher than the pre-crisis level in Spain. In the "high θ " case debt de-laveraging takes place and the ratio of debt to durables decreases to the pre-crisis level. Table 3 reveals that excess sensitivity is only relevant for the first three quintiles, for the others no significant impact of (lagged) income growth on consumption growth is found. Significant differences in the impact can be found with values on average higher than those found in Luengo-Prado (2006). The sensitivity to the down payment constraint can be seen clearly and the reactions of consumption to income are expected to be higher in times of more binding liquidity constraints.

The energy expenditure of households is based on consumption expenditure data from EUROSTAT, the Energy Accounts from the WIOD database, as well as IEA Energy Prices. In order to calculate service prices, energy efficiency data had to be added. Energy efficiency for electricity is calculated as a weighted average of efficiency of electrical appliances from the ODYSSEE database. The efficiency for heating is approximated by the indicator for heating efficiency in the ODYSSEE database. Heat efficiency of the car fleet could in a revised version also be taken from the database of the GAINS project. The durable stock of households (vehicles, houses, appliances) embodies the efficiency of converting an energy flow into a service level. Policy measures that increase the efficiency of the new durables purchased or speed up the renovation of the durable stock by premature scrapping, therefore lead to less direct energy demand of households and rebound effects from higher service demand. The panel data set resulting from this data collection process comprises all EU 27 countries. Table 4 shows that the implicit price elasticities of transport demand are relatively high. Note that due to the fact that the consumption variables for energy on the left hand side are in current prices, the price elasticity is given by 1 minus the corresponding parameter (γ_{fuel}, γ_{heat}, and γ_{el}). The expenditure elasticity of total transport demand is considerably below unity and the density of vehicle endowment is an important factor that dampens demand for driving. Table 5 also reveals relatively high price elasticities for given durable stocks and controlling for climate conditions.

The results of the estimation of the demand system for non-energy nondurables are condensed in Table 6. While the expenditure elasticities are closely distributed around unity, the price elasticity shows more heterogeneity across categories. This elasticity mainly determines the reactions to commodity taxation in consumption.

All data for the production system are derived from the WIOD (World Input Output Database) dataset that contains World Input Output Tables (WIOT) in current and previous year's prices, Environmental Accounts (EA), and Socioeconomic Accounts (SEA). The latter are used to derive data for capital and labour, like the base year capital stock and depreciation rates as well as labour compensation by hour and by person. From the EA we use data of energy use by 25 energy carriers in physical units (TJ) and CO_2 emissions and combine the physical energy inputs with information on energy prices from the IEA to get a full system of energy quantities and prices. The WIOT in current and previous year's prices have been used to derive quantities and prices for (M^m) and (M^d).The system of the unit cost function and the factor cost shares has been estimated with panel data econometrics for 23 EU countries with time series from 1995 to 2009. The systems have been estimated applying the Seemingly Unrelated Regression (SUR) estimator for balanced panels under cross section fixed effects for each of the 35 industries (345 observations). The estimation results yield parameter values for all price terms which together with the factor cost shares give the own and cross price elasticity according to the formulae for the Translog model. Table 7 to 10 contain the price elasticities for capital, labour, energy, and imported intermediates respectively. The own price elasticity of labour is on average about -0.5, with relatively high values in some manufacturing industries. The own price elasticity of energy is very heterogenous across industries and rather high in energy intensive industries.These elasticities have then in turn been used to calibrate the production system for the DYNK model base year (2005) for Spain.

Table 11 shows the double impact of autonomous technical change on factor demand from TFP that decreases unit costs and therefor factor inputs and from the factor bias that either decreases or increases factor input in an industry. A great variety of elasticity values can be observed from that.

Wage data including hours worked are taken from WIOD Sectoral Accounts and are complemented by labour force data from EUROSTAT. The wage equations have been estimated for the full EU 27 panel including lags of some of the independent variables as well as of the wage rate per hour (ADL specification). Table 12 only shows the short-run coefficients, the long-run elasticities are considerably larger and for the unemployment elasticity (ur^*/ur_t) the unweighted average across industries is about 0.09. The long-run productivity elasticity of wages is also correspondingly higher and almost unity. Not all industries show a significant impact of hours worked on the hourly wage rate. In industries without this coefficient in the wage curve, a reduction of hours worked *ceteris paribus* leads to a proportional income loss of workers.

3. Mid-term scenarios for the Spanish economy

The DYNK model has been solved for a baseline scenario from the base year 2005 to 2030, taking into account recent data until 2012 and after that making assumptions about the development of exogenous variables. Import prices, especially for energy, a simple (autoregressive) forecast of exports, interest rates, house prices, as well as detailed population and labour force projections are the main exogenous variables in this model. An important constraint is the long-run value of θ that is to be achieved on average for the household debt ratio. For a baseline scenario we use the assumption of the "high θ case" described above, where the debt to durables ratio converges back to the pre-crisis level. Another constraint is the public deficit stability program of Spain, defined as a target path of government net lending as percentage of GDP until 2018. This is guaranteed by endogenizing public consumption according to (46). Tax and transfer policies with respect to their distributional impact across the five income groups also remain constant for the baseline scenario. In general, the debt de-leveraging process of households and the government net lending constraint dampen the economy until 2018. The level of GDP in constant prices of 2009 is only reached in 2017 and the Spanish economy starts growing from then on. The average growth rate of GDP at constant prices between 2009 and 2030 is about 1.5% p.a. in this baseline scenario. The growth rates of TFP by industry have been set constant during the simulation period, i.e. no acceleration of TFP growth by specific innovation activities has been assumed. The factor bias of technical change has also been kept constant and had to be dampened in the case of energy, as well as at the K, L, E, M^m, M^d level of factor demand as in the fuel submodel in order to avoid negative values for shares of energy (e.g. in some service sectors) or for shares of some fuels (e.g. coal).

The rate of unemployment rises until 2018 and stays above 20% and then continuously decreases, as with higher GDP growth employment is generated and labour supply does not increase strongly. Wage inflation stays low at the beginning due to big difference between the actual and the full employment rate of unemployment.

Emissions of greenhouse gases (GHG) continuously rise and reach the pre-crisis level after 2025, which is due to a large impact of the crisis on emissions and some relative decoupling until 2030.

3.1 Labour market policies

From 2000 to 2007 the Spanish economy has been growing very rapidly and according to concepts of potential output most time above the potential output growth (Borio, et al., 2013). This unsustainable growth path in turn has reduced unemployment considerably (Domenech, 2013). Like in Faia, et al. (2013) therefore in this study the potential of labour market reforms shall be analysed to directly deal with this situation of high unemployment in Spain. The existing literature on labour market reforms has identified several reform measures that worked out in reducing unemployment across different countries (Chepta, et al., 2014). There have - on the other hand - also institutional factors been identified that limit the transmissibility of reforms across countries (Sachs and Schleer, 2013). General aspects of labour market reforms comprise increasing the efficiency of the matching process, and in general increasing incentives at the demand and supply side of the labour market for accepting jobs and filling vacancies.

Recent literature on the German labour market reforms (the so-called Hartz reforms) and the German short-time work sheme ("Kurzarbeit") comprise Arent and Nagl (2013), Hunt (2013), Dustmann, et al. (2014) and Krebs and Scheffel (2013), who present estimated macroeconomic effects of the German labour market reforms. One common effect detected and analysed is the increase in the matching efficiency that took place in Germany after 2000. In the case of Spain it turns out that according to official data the relationship between unemployed and vacancies is close to a value of 100. In this situation, policies that increase the matching efficiency measured by this data have a very limited scope for lowering unemployment. Therefore we concentrate on hiring subsidies, also analyzed in Busl and Seymen (2013) as well as on short-time work (German "Kurzarbeit") modeled in Faia et al. (2013).

The labor market policies simulated for Spain therefore comprise hiring subsidies for green jobs and the introduction of short-time work in all industries. Based on results about the potential for green jobs in Spain (ILO, 2012), the basic metal industry and the construction sector have been selected for these measures. The detailed assumptions for the implementation of these labour market policies in the DYNK model are:

- The recycling share in metal industry output rises from 60% to 80%, which leads (based on the data in ILO, 2012) to estimated reductions of 35% in the average energy intensity.

This is brought about by hiring subsidies in the magnitude of 40% of the social security contributions (on average) in the recycling industry

- Persons employed in the refurbishment of the Spanish housing stock receive hiring subsidies that amount to 30% of the social security contributions (on average) in the construction industry. This leads to a continous increase in the heating efficiency above its baseline value (7% above the baseline in 2020 and 15% in 2030). That corresponds to the exhaustion of only a part of the potential according to ILO (2012)
- The introduction of short-time work across all industries leads to a continous reduction in the variable hours/employee in all industries to a maximum of 12%, which corresponds to five hours over a base of 40 hours. This shortening of work time is reached in a continous way and after that the variable hours/employee slightly rises again to a value that corresponds to a 5% reduction in working time. That corresponds to the extrapolation of the trend in this variable until 2030.

The hiring subsidies push labour demand in the two affected industries and lower output prices correspondingly, leading to higher demand. This in turn drives output effects in these two industries and spillovers to others. The energy efficiency effect in heating due to the refurbishment activities leads to lower energy demand, but price rebound effects and higher output partly compensate this pure engineering effect.

The introduction of short-time work reduces the work time and like in Faia, et al. (2013) avoids job destruction, although hiring and firing are not explicitly modeled in the labour market of the DYNKL model. The labour demand function determines the wage sum which together with the hourly wage rate from the wage curves allows for calculating the volume of hours. Given the simultaneous bargaining over wages and hours, in some industries the hourly wage rate rises in reaction to short-time work, thereby increasing labour costs and output prices. The wage feedback is nevertheless too small to compensate workers for income losses for short-time work. The simulations are complemented by a lump-sum compensation to the two lower quintiles in order to compensate for most of the income losses along the simulation path. This compensation is financed in a revenue neutral way within total public transfer payments, as the share of total transfers accruing to the upper two quintiles is reduced accordingly.

As Table 13 shows, GDP and its demand components are positively stimulated at the beginning of the simulation period, when worktime is only reduced slightly and the positive impact of hiring subsidies creates employment and output effects. This is also the main argument in Faia, et al. (2013) and Busl and Seymen (2013), namely that an increase in the hiring activities of firms, due to increased matching efficiency or hiring subsidies also has a macroeconomic multiplier effect. Short-time work in the DYNK model leads to higher employment (persons), but lower demand for hours worked, as costs and prices increase and output decreases accordingly. Although the labour market policies lead to an output decrease (compared to the baseline), a considerable employment effect in persons is observed and the unemployment rate can be reduced by about 5 percentage points. The GHG emissions also are slightly reduced due to the energy saving impact of the new green jobs, created by hiring subsidies.

The real disposable income of households (Table 14) is decreased on average over all income gropus, though less than output. The transfer policies keep the income losses for the first two quintiles almost zero over the simulation period (2nd quintile) or even increase real disposable income (1st quintile), whereas the other income groups occur income losses due to short-time work. These simulations do not assume a well elaborated compensation scheme of income losses from sort-time work, but show that these policies should in principle be viable.

Graph 1 shows the employment effects of this policy by industry. The two industries affected by hiring subsidies reveal different employment effects with respet to the average employment effect. The secondary raw materials industry increases employment by almost 20% compared to the baseline, whereas the employment increase in the construction sector is only slightly above the averay employment effect. This is due to the wage feedback effect of short-time work that is much higher in construction than in secondary raw materials (part of "other manufacturing" in Table 12).

3.2 Environmental fiscal devaluation

On a theoretical and empirical macroeconomic level fiscal devaluation is well researched. In this study the concept of fiscal devaluation is applied to environmental tax reforms. One of the main problems with traditional environmental taxation at the European level is the competitiveness effect on European industry which in the worst case only leads to delocation of CO_2-intensive productions. As CO_2 is a global externality, this does not contribute to the environmental goal (‘carbon leakage’) and additionally reduces output, welfare, and employment in Europe. Taking these arguments into account, a different tax reform is analysed in this study, which could be labeled as 'environmental fiscal devaluation'. The basic idea is – instead of taxing the GHG emissions of domestic production – to tax the consumption of broad categories (commodities in the DYNK model) according to their embodied GHG emissions.

The starting point for this exercise is a series of simulations with the DYNK model for each private consumption category in order to obtain domestic and imported embodied GHG emissions for each category (GHG per unit of consumption in current prices). The imported embodied GHG emissions are calculated by applying the GHG emission coefficients per unit of domestic output to imports, i.e. assuming the same technology. The tax rate for GHG emissions introduced until 2030 follows the lines of the impact analysis of the EU roadmap 2050 (European Commission, 2011) for emission reductions. The detailed assumptions for the implementation of environmental fiscal devaluation in the DYNK model are:

- Embodied GHG of each of the 59 consumption commodities in the DYNK model is taxed with a rate of 25€/t Co2eq increasing up to 144€/t (in constant € 2005). Fuel for heating and transport directly linked to GHG emissions of households are also taxed accordingly.

- This tax on embodied GHG emissions is compensated by an *ex ante* revenue neutral reduction in an employer's and emoployee's social security contributions.

On average, the resulting tax rates correspond to an *ad valorem* tax of about 3% in 2020, but there are considerable differences across commodities. In 2020 selected consumption commoditiers in the DYNK model are charged with the following tax rate (in %):

- Pulp, paper and paper products	2.7%
- Chemicals, chemical products	2.5%
- Motor vehicles	1.1%
- Electrical energy, gas, steam	11.2%
- Retail trade services	0.1%
- Hotel and restaurant services	2.6%
- Land transport, pipelines	6.2%

- Air transport services	8.4%
- Other services	4.0%
- Heating fuels	20.8%
- Fuels for transport	13.7%

Energy and directly energy intensive commodities reveal very high tax rates, which might create regressive effects on income distribution. Therefore, the same lump-sum compensation to the two lower quintiles as in the labour market policy-scenario is upheld (the share of total transfers accruing to the upper two quintiles is reduced and the share to the two lower quintiles increased accordingly).

Table 15 shows the expected results of environmental fiscal devaluation on GDP and the final demand components. Like currency devaluation, this policy increases consumer prices and decreases output prices and therefore shifts demand from consumption to exports with an overall positive impact on GDP. Employment increases slightly more than GDP, but considerably more than gross output (not shown here), which only increases about 2%. This is due to important structural changes driven by this tax reform, shifting demand and production to more employment- and value added-intensive industries away from energy-intensive activities. The unemployment rate is reduced by 5 percentage points in the mid-term by this policy. Total GHG emissions are about 3% below the value in the baseline. Household's direct emissions are reduced more at the beginning of the simulation period. The long-run decrease in households' emission reduction is due to price and income rebound effects that drive energy demand in the mid-term (e.g. higher durable stocks of households). There is an important difference in the impact on global GHG emissions of this policy compared to traditional environmental tax reform. Traditional environmental tax reform introduced in one region leads to competitiveness effects and delocation of activities that increase GHG emissions abroad ('carbon leakage'). In contrast this policy reduces imports due to the taxation of consumption and therefore also reduces GHG emissions abroad. Applying the GHG emission coefficients per unit of domestic output to imports, yields the reduction of GHG emissions abroad induced by this policy. This 'negative carbon leakage' amounts to 25% of the domestic emission reduction effect.

Durable consumption (Table 16) slightly rises compared to the baseline, nondurable expenditure stays constant and energy expenditure decreases, though consumers' energy prices increase substantially due to real demand effects. Across quintiles of household income no clear picture emerges, the redistribution scheme applied does not redistribute towards the lower quintiles over the whole simulation period. This is mainly driven by the structure of price changes and is a clear indication of potential energy poverty effects associated with this policy. Different and more elaborated compensation schemes needed to be adopted in order to rule out this development.

Graph 2 depicts the employment effects by industry showing a large heterogeneity across industries. Some industries (tobacco products, transport services) even decrease employment compared to the baseline. Value-added intensive industries in general expand employment above the average employment effect.

3.3 The combined policy scenario

The combined policy scenario implements both policies in one scenario and also applies the original lump-sum compensation by redistributing public transfers towards the two lower quintiles of the household income distribution as in the labour market policy-scenario. The different impacts of policies overlap in this scenario. This can best be seen in the effects on GDP and final demand components (Table 17) which start with positive or neutral initial impacts and end up with negative differences to the baseline. Especially consumption is negatively affected, as the policies analysed have a negative consumption-bias: short-time work leads to income losses that are only partly compensated and environmental fiscal devaluation shifts resources from consumption to exports. Employment increases by almost 10% and the unemployment rate is reduced by about 7 percentage points. GHG emissions are 5% under the baseline in 2030 with emission reduction in production making the main contribution to this result.

The negative impact on consumption in this combined policy-scenario can also be seen in Table 18 with durable and energy consumption most affected. The distributional impacts of this scenario are regressive, though the transfer redistribution scheme of the labour market policy-scenario is in place. This is a clear indication for a trade-off between macroeconomic policy targets and the target of income distribution. Different and more elaborated compensation schemes needed to be designed in order to rule out these regressive distributional impacts.

Graph 3 depicts the overall positive employment effects of the combined policy-scenario which are heterogenous and similar to the employment effects of the labour market-policy scenario that dominates the results. Also the large positive impact of hiring subsidies in the secondary raw materials industry can be seen in the results of this scenario.

The three policy scenarios deviate considerably from the baseline development in the case of the unemployment rate (Graph 4). The impact of the environmental fiscal devaluation-scenario on the unemployment rate is smaller than the impact of the labour market-policy-scenario. The results of the combined policy-scenario clearly show that the unemployment rate could be reduced considerably, especially in the period of massive public deficit reduction (until 2018). Graph 5 shows the small differences in the development of GDP at constant prices for the four scenarios. In the short-term all policy scenarios result in slightly higher GDP levels than the baseline. After 2020 GDP in the labour market policy-scenario is continuously below the level of the baseline scenario. The average growth rate difference from 2009 to 2030 is about 0.25 percentage point p.a., as GDP grows with 1.5% p.a. in the baseline and with 1.25% p.a. in the labour market policy-scenario. The average GDP growth rate in the environmental fiscal devaluation-scenario is 1.75% p.a., i.e. 0.25 percentage points higher than in the baseline. The combined policy-scenario shows almost the same development in GDP at constant prices as the baseline scenario.

4. Conclusions

The starting point of this paper was the economic and social situation in Spain in the aftermath of the Great Recession 2009, characterized by high public and private (household) debt and high unemployment rates as well as serious social problems caused by austerity policies. One outstanding problem is that job creation stays relatively low for some period, leading to sustained high unemployment rates. The focus of this paper is on policy options for lowering unemployment and fostering GDP growth, given the public debt and deficit constraints. These policy options can be discussed from the perspective of their short-term contribution to alleviating the post-crisis economic and social problems, as well as their impact on mid-term strategic targets of European social and environmental policy, especially in energy and climate policy.

This paper presents the model blocks and features of the DYNK (Dynamic New Keynesian) model for Spain (household behavior, firm behavior, labour market, government sector, and model closure) and then deals with two main policy options that can be implemented without violating the public debt-targets: (i) active labour market policies (hiring subsidies and short-time work), and (ii) environmental fiscal devaluation (lower social security contributions balanced by taxes on GHG emissions embodied in consumption).

The results show that both policy options have an important impact on unemployment which would – given the public budget constraints until 2018 – increase slightly in the baseline scenario. The impacts on other macroeconomic variables are different in the two policy scenarios and a combined policy-scenario leads to significant short-term changes in the Spanish labour market with a reduction in the unemployment rate of about 7 percentage points compared to the baseline. In both policy scenarios GHG emissions are also slightly reduced compared to the baseline. These reductions are small compared to the mid-term targets of European energy and climate policy, therefore the policies analysed can only be qualified as not being counterproductive for mid-term targets, but do not suffice to also achieve these targets. For GDP at constant prices the two policy scenarios deviate from the baseline in different ways, whereas the combined policy-scenario reveals almost the same path for GDP as the baseline. In the labour market policy-scenario GDP is lower in the mid-term due to the wage cost feedback effect of short time-work, whereas in the environmental fiscal devaluation-scenario GDP is higher due to improved price competitiveness.

The potential regressive distributional impacts of these policies have been partly compensated by a simple public transfer compensation scheme. Basically, this scheme consists of a different distribution of public transfers across the two lower and the two upper quintiles. This distributional compensation turned out to actually compensate regressive effects of policies in the case of labour market policy, but the same scheme did not work out for environmental fiscal devaluation and for the combined policy-scenario. This is especially relevant to avoid energy poverty in the case of environmental fiscal devaluation, where energy costs rise substantially for households. Future research needs to engage more on the distributional impacts of tax and transfer system reforms in a broader perspective in order to complement the policies analysed in this paper.

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Table 1: Estimation results for durable and nondurable demand (EU 14, 1995 – 2012)

	$\log C_{dur,t}$ (own houses)	$\log C_{dur,t}$ (vehicles)	$\log C_t$
long-run parameters			
$\log (X_t)$	1.417	0.812	0.819
θ_t	-0.120	-0.020	
$\log(p_{dur,t})$	-	0.855	
$\log (X_t) \log(K_{t-1} / hh_{t-1})$	-0.040	-0.017	
$\theta_t \log(C_{dur,t})$	-	-	-0.009
short-run parameters			
$d\log (X_t)$	0.900	0.431	0.232
	(0.12)	(0.09)	(0.05)
$d\theta_t$	-0.035	-0.017	
	(0.01)	(0.01)	
$d\log(p_{dur,t})$	-	0.911	
		(0.14)	
ECM	-0.181	-0.356	-0.144
	(0.03)	(0.05)	(0.03)
R^2	0.44	0.40	0.38
D.W.	1.76	2.03	2.09
S.E. of regression	0.22	0.12	0.11

Table 2: Marginal propensity of consumption (in relation to cash on hand) by income groups (Spain, 2005)

	1st quintile	2nd quintile	3rd quintile	4th quintile	5th quintile
own houses	1.24	1.23	1.22	1.21	1.19
vehicles	0.78	0.78	0.77	0.77	0.77
nondurables	0.82	0.82	0.82	0.82	0.82

Table 3: Excess sensitivity by income groups (Spain, 2005 – 2050)

Sensitivity										
	1st quintile		2nd quintile		3rd quintile		4th quintile		5th quintile	
dlog(C_{dur})	0.54	***	0.43	***	0.40	***	0.38	***	0.41	***
	(0.13)		(0.11)		(0.13)		(0.11)		(0.10)	
dlog(C)	1.52	***	0.56	**	0.30	**	0.11		-0.13	
	(0.52)		(0.23)		(0.16)		(0.13)		(0.15)	
Sensitivity, high θ										
	1st quintile		2nd quintile		3rd quintile		4th quintile		5th quintile	
dlog(C_{dur})	0.55	***	0.44	***	0.42	***	0.39	***	0.41	***
	(0.12)		(0.11)		(0.13)		(0.11)		(0.10)	
dlog(C)	1.55	***	0.60	***	0.34	**	0.15		-0.13	
	(0.53)		(0.23)		(0.17)		(0.14)		-(0.13)	

Table 4: Estimation results for transport demand of households (EU 27, 1995 – 2012)

	$\log CP_{tr}$		$\log CP_{fuel}/\log K$	
$\beta_{tr,1}$	0.1876	***		
	(0.0315)			
$\beta_{tr,2}$	0.6140	***		
	(0.0400)			
γ_{fuel}			0.2285	***
			(0.0478)	
ξ_{fuel}			-0.3402	***
			(0.0577)	
R^2	0.9994		0.9639	
D.W.	1.0248		1.3353	
S.E.of regression	0.0622		0.1016	

Table 5: Estimation results for electricity and heating fuels demand of households (EU 27, 1995 – 2012)

	$\log CP_{el}/\log K$		$\log CP_{heat}/\log K$	
γ_{heat}			0.1319	***
			(0.0346)	
ξ	0.1038	**	0.5093	***
	(0.0442)		(0.0860)	
γ_{el}	0.1859	***		
	(0.0182)			
R^2	0.9829		0.9958	
D.W.	1.6413		1.6813	
S.E.of regression	0.0857		0.2007	

Table 6: Price elasticity of nondurable demand of households (EU 27, 1995 – 2012)

	own price elasticity	expenditure elasticity
Food	-0.142	0.882
Clothing	-0.638	1.010
Furniture	-1.057	1.061
Health	-0.827	0.977
Communication	-0.886	1.031
Recreation	-0.504	1.060
Financial services	-0.937	1.253
Other	-0.684	1.071

Table 7: Price elasticity of K (EU 23, 1995 – 2009)

K	K	L	E	M^m
Agriculture,	-2.88	0.94	0.34	0.71
Mining, quarrying	-0.70	0.31	0.15	0.12
Food, beverages	-0.62	-0.09	-0.06	0.20
Textiles	-0.89	0.43	0.01	0.39
Leather, footwear	-0.99	0.48	0.31	0.41
Wood and cork	-0.47	0.00	-0.09	-0.03
Pulp,paper	-0.96	-0.10	-0.05	0.22
Coke, refinery	0.00	0.00	0.00	0.00
Chemicals	-0.91	0.10	0.35	0.22
Rubber and plastics	-0.74	0.11	-0.04	0.11
Non-metallic minerals	-1.17	0.23	-0.06	0.06
Basic metals	-1.09	0.20	0.28	0.34
Machinery	-1.21	0.20	0.01	0.24
Electrical equipment	-0.62	0.15	-0.14	0.00
Transport equipment	-1.06	-0.12	-0.10	0.20
Other manufacturing	-1.29	1.06	-0.06	0.47
Electricity, gas, water	-1.08	0.17	0.57	0.08
Construction	-0.40	-0.14	-0.01	0.17
Sale of motor vehicles	-0.25	0.37	0.49	0.26
Wholesale trade	-0.64	-0.12	-0.03	0.20
Retail trade	-0.50	-0.63	0.20	0.50
Hotels, restaurants	-0.58	-0.21	0.03	0.24
Other Inland transport	-0.79	0.09	-0.01	0.11
Other Water transport	0.00	0.00	0.00	0.00
Other Air transport	-1.24	-0.21	-0.01	0.50
Other transport activities	-0.93	0.04	-0.12	0.12
Post, telecommunications	-0.63	0.29	-0.08	-0.01
Financial Intermediation	-0.93	0.21	-0.06	0.39
Real estate activities	-0.49	0.05	0.01	0.16
Other business activities	-0.68	-0.02	0.01	0.17
Public Administration	-1.00	0.96	0.26	-0.09
Education	-0.91	0.66	0.12	0.02
Health	0.00	0.52	0.57	0.30
Social,personal services	-0.80	0.09	0.01	0.09

Table 8: Price elasticity of L (EU 23, 1995 – 2009)

L	K	L	E	M^m
Agriculture,	0.12	-0.49	0.10	0.18
Mining, quarrying	0.37	-0.33	0.01	0.04
Food, beverages	-0.07	-0.62	-0.12	0.33
Textiles	0.22	-0.72	0.09	0.08
Leather, footwear	0.25	-1.10	-0.42	0.13
Wood and cork	0.01	-0.65	0.06	0.26
Pulp,paper	-0.07	-0.58	0.02	0.36
Coke, refinery	0.00	0.00	0.00	0.00
Chemicals	0.14	-0.72	0.06	0.55
Rubber and plastics	0.08	-0.61	0.09	0.46
Non-metallic minerals	0.18	-0.50	0.10	0.22
Basic metals	0.11	-0.57	0.00	0.51
Machinery	0.09	-0.65	0.00	0.35
Electrical equipment	0.09	-0.60	-0.02	0.43
Transport equipment	-0.13	-0.71	0.04	0.75
Other manufacturing	-0.15	-0.63	-0.01	0.31
Electricity, gas, water	0.35	-0.54	0.50	-0.03
Construction	-0.06	-0.59	0.06	0.11
Sale of motor vehicles	0.25	-0.64	-0.32	0.21
Wholesale trade	-0.06	-0.54	0.11	0.12
Retail trade	-0.08	-0.38	0.09	0.11
Hotels, restaurants	-0.06	-0.36	0.02	0.07
Other Inland transport	0.02	-0.46	0.12	0.13
Other Water transport	0.00	0.00	0.00	0.00
Other Air transport	-0.15	-0.49	0.04	0.12
Other transport activities	0.01	-0.90	-0.14	0.18
Post, telecommunications	0.40	-0.66	0.08	0.02
Financial Intermediation	0.22	-0.66	-0.09	0.23
Real estate activities	0.17	-0.09	-0.41	-0.13
Other business activities	0.00	-0.37	0.10	0.10
Public Administration	0.26	-0.71	-0.14	0.02
Education	0.08	-0.24	-0.02	0.02
Health	0.13	-0.42	-0.05	0.08
Social,personal services	0.07	-0.43	0.09	0.07

Table 9: Price elasticity of E (EU 23, 1995 – 2009)

E	K	L	E	M^m
Agriculture,	0.48	1.07	0.00	0.10
Mining, quarrying	0.77	-0.05	-0.18	0.01
Food, beverages	-0.43	-0.93	-0.25	0.11
Textiles	0.02	0.86	0.00	1.15
Leather, footwear	2.20	-6.21	-4.09	3.58
Wood and cork	-0.42	0.47	-0.26	0.44
Pulp,paper	-0.36	0.14	-0.32	-0.57
Coke, refinery	0.00	0.00	0.00	0.00
Chemicals	1.49	0.14	-0.97	-0.49
Rubber and plastics	-0.24	0.56	-0.63	-0.28
Non-metallic minerals	-0.26	0.37	-0.52	0.11
Basic metals	0.85	-0.05	-1.05	0.47
Machinery	0.04	-0.06	-0.32	1.19
Electrical equipment	-1.98	-0.36	-0.48	0.04
Transport equipment	-0.89	0.49	-0.27	-0.75
Other manufacturing	0.46	-0.18	-0.42	-0.48
Electricity, gas, water	0.53	0.24	-0.68	0.14
Construction	-0.09	1.01	-0.66	0.93
Sale of motor vehicles	5.06	-4.96	-0.43	-1.21
Wholesale trade	-0.42	1.92	0.00	0.32
Retail trade	1.06	1.69	0.00	-0.12
Hotels, restaurants	0.21	0.19	-0.31	0.20
Other Inland transport	-0.11	0.58	-0.30	-0.18
Other Water transport	0.00	0.00	0.00	0.00
Other Air transport	-0.07	0.11	-0.32	0.36
Other transport activities	-1.66	-1.71	-1.91	-0.06
Post, telecommunications	-1.95	1.52	0.00	2.35
Financial Intermediation	-1.84	-3.75	0.00	-5.00
Real estate activities	-3.31	-6.19	-0.47	-1.93
Other business activities	0.24	2.94	0.00	-0.09
Public Administration	1.49	-3.61	-1.44	1.36
Education	1.21	-1.41	0.00	0.00
Health	2.77	-1.63	-0.10	-1.12
Social,personal services	0.04	1.22	-0.42	0.12

Table 10: Price elasticity of M^m (EU 23, 1995 – 2009)

M^m	K	L	E	M^m
Agriculture,	0.37	0.73	0.04	-1.03
Mining, quarrying	0.27	0.10	0.03	-0.56
Food, beverages	0.21	0.38	0.02	-0.67
Textiles	0.19	0.06	0.12	-1.07
Leather, footwear	1.53	-1.07	3.58	-1.72
Wood and cork	-0.03	0.33	0.07	-0.66
Pulp,paper	0.17	0.41	-0.07	-0.93
Coke, refinery	0.00	0.00	0.00	0.00
Chemicals	0.16	0.31	-0.05	-0.84
Rubber and plastics	0.05	0.35	-0.03	-0.92
Non-metallic minerals	0.04	0.29	0.04	-0.90
Basic metals	0.13	0.37	0.06	-0.30
Machinery	0.10	0.34	0.08	-1.65
Electrical equipment	-0.02	0.25	0.01	-0.73
Transport equipment	0.06	0.45	-0.03	-1.27
Other manufacturing	0.00	0.40	-0.04	-0.68
Electricity, gas, water	0.28	-0.09	0.52	-1.57
Construction	0.17	0.19	0.10	-0.59
Sale of motor vehicles	0.50	0.60	-0.23	-1.01
Wholesale trade	0.59	0.43	0.07	-0.96
Retail trade	0.95	0.70	-0.04	-1.44
Hotels, restaurants	0.54	0.29	0.07	-0.83
Other Inland transport	0.23	0.54	-0.15	-0.88
Other Water transport	0.00	0.00	0.00	0.00
Other Air transport	0.44	0.12	0.12	-1.24
Other transport activities	0.22	0.38	-0.01	-0.93
Post, telecommunications	-0.04	0.02	0.37	-0.29
Financial Intermediation	1.69	1.19	-0.71	0.00
Real estate activities	5.34	-0.20	-0.21	-1.98
Other business activities	0.47	0.39	-0.01	-0.98
Public Administration	-0.16	0.03	0.46	-0.71
Education	0.02	0.29	0.00	-1.48
Health	0.36	0.40	-0.26	-1.27
Social,personal services	0.20	0.27	0.04	-0.84

Table 11: Elasticity of fator demand to technical change (TFP plus bias, EU 23, 1995 – 2009)

t	K	L	E	M^m
Agriculture,	-0.125	-0.022	-0.121	0.006
Mining, quarrying	0.066	-0.032	0.010	0.039
Food, beverages	0.024	0.003	0.007	0.018
Textiles	-0.016	-0.020	-0.087	-0.016
Leather, footwear	-0.027	0.018	0.305	-0.018
Wood and cork	-0.009	-0.018	-0.045	0.005
Pulp,paper	-0.008	-0.017	-0.056	-0.007
Coke, refinery	0.000	0.000	0.000	0.000
Chemicals	-0.013	-0.023	0.012	0.005
Rubber and plastics	-0.004	-0.035	-0.061	-0.006
Non-metallic minerals	-0.013	-0.031	-0.044	-0.008
Basic metals	-0.008	-0.020	-0.015	0.024
Machinery	-0.001	-0.030	-0.125	-0.016
Electrical equipment	-0.018	-0.039	-0.231	-0.005
Transport equipment	0.012	-0.040	-0.144	0.001
Other manufacturing	-0.054	-0.035	-0.025	0.013
Electricity, gas, water	-0.004	-0.047	0.028	-0.010
Construction	0.031	-0.001	-0.016	0.022
Sale of motor vehicles	-0.009	-0.013	0.059	0.000
Wholesale trade	-0.002	-0.021	-0.119	0.001
Retail trade	0.001	-0.017	-0.095	-0.017
Hotels, restaurants	0.016	0.005	-0.033	0.013
Other Inland transport	0.007	-0.019	0.006	0.033
Other Water transport	0.000	0.000	0.000	0.000
Other Air transport	-0.007	-0.061	0.024	0.000
Other transport activities	0.002	0.025	0.289	0.019
Post, telecommunications	-0.018	-0.049	-0.193	0.014
Financial Intermediation	-0.012	-0.027	-0.016	0.000
Real estate activities	0.012	0.034	-0.062	0.213
Other business activities	-0.003	-0.002	-0.204	0.010
Public Administration	-0.017	0.008	0.167	0.006
Education	0.006	0.000	-0.014	0.008
Health	0.014	0.004	-0.031	0.027
Social,personal services	0.024	-0.008	-0.047	0.020

Table 12: Estimation results of industry wage equations (EU 27, 1995 – 2009)

	$\log(PC_{t-1})$		$\log(Q_{i,t-1}/H_{i,t-1})$		$\log(ur^*/ur_t)$		$\log(H_{i,t}/L_{i,t})$		R^2	D.W.
Agriculture,	0.289	***	0.133	**	0.019	*	-	0	1.000	1.717
Mining, quarrying	-		0.438	*	0.054	***	-	0	0.998	2.048
Food, beverages	0.268	***	0.100	*	0.015	***	-	0	0.999	1.983
Textiles	0.019	*	0.036	**	0.048	***	-	0	0.999	1.739
Leather, footwear	0.442	***	-		0.001	***	-0.334	***	1.000	2.218
Wood and cork	0.315	***	0.040		0.024	***	-0.013	***	0.999	1.947
Pulp,paper	0.181	***	0.055	***	0.021	**	-0.007	***	0.999	1.957
Coke, refinery	0.043	*	-		0.007		-		1.000	1.980
Chemicals	0.175	***	0.031	*	0.024	**	-0.046	***	0.999	1.845
Rubber and plastics	0.291	***	0.114	**	0.011	***	-		0.999	2.019
Non-metallic minerals	0.323	***	0.223	**	-		-0.224	***	0.999	1.891
Basic metals	0.267	*	0.083	**	0.017	***	-0.051	***	1.000	1.830
Machinery	0.231	***	0.026	*	0.026	***	-		0.999	1.870
Electrical equipment	-		0.156	*	0.003	***	-		0.999	2.052
Transport equipment	0.170	***	0.090	***	0.009		-0.155	***	0.999	2.278
Other manufacturing	0.138	***	0.020	*	0.018	*	-0.029	***	0.999	2.019
Electricity, gas, water	0.181	***	0.233		0.023	**	-0.121	***	0.999	2.109
Construction	0.232	***	0.052	**	0.032	***	-0.145	***	0.999	1.825
Sale of motor vehicles	0.265	***	0.027		0.020	***	-0.080	***	0.999	1.859
Wholesale trade	0.342	***	0.057	***	0.009	***	-0.213		0.999	1.768
Retail trade	0.138	***	0.213	***	0.015	***	-0.244	***	1.000	1.801
Hotels, restaurants	0.088		0.158	***	0.033	***	-	0	0.999	1.980
Other Inland transport	0.169	***	0.050	**	0.028	***	-0.150	***	0.999	1.693
Other Water transport	0.223	***	0.036	***	0.008		-0.145	***	0.996	1.968
Other Air transport	0.113	**	0.027		0.022	*	-0.197	***	0.997	1.798
Other transport activities	0.330	**	0.290	***	0.010	***	-0.202	***	0.999	1.616
Post, telecommunications	0.232	***	0.150	**	0.021		-0.112	***	0.999	1.620
Financial Intermediation	0.125	***	0.125	***	0.026	***	-	0	0.999	2.019
Real estate activities	0.235	***	-		0.017	***	-0.071	***	0.999	2.015
Other business activities	0.428	***	0.059	*	0.030	***	-0.242	*	0.999	1.951
Public Administration	0.223	*	0.210	**	0.021	***	-	0	0.999	1.872
Education	0.136	***	0.124	***	0.020	***	-	0	0.999	1.703
Health	0.187	**	0.180	***	0.031	***	-0.182	***	0.999	1.880
Social,personal services	0.000		0.365	***	0.005	***	-		0.999	1.720

Table 13: Aggregate effects in the 'Labour market policy' scenario (difference to baseline)

	2015	2020	2030
GDP, const. prices	1.07	-3.38	-4.53
Private Consumption, const. prices	0.28	-1.89	-2.15
Capital formation, const. prices	0.02	-0.03	-0.04
Exports, const. prices	0.33	-2.96	-3.54
Employment (persons)	7.27	5.97	3.98
Unemployment (persons)	-26.31	-22.72	-24.56
Unemployment rate (% points)	-5.70	-4.73	-3.42
GHG emissions, households	-0.15	-0.47	-1.47
GHG emissions, production	0.35	-1.31	-1.78
GHG emissions, total	0.26	-1.17	-1.74

Table 14: Income and consumption effects in the 'Labour market policy' scenario (difference to baseline)

	2015	2020	2030
Durable consumption, const. prices	0.58	-1.33	-1.49
Nondurable consumption, const. prices	0.00	-0.02	-0.03
Energy, const. prices	0.06	-0.07	-0.18
Real disposable income	2015	2020	2030
Total	-0.01	-1.96	-2.01
1st quintile	1.59	0.15	1.23
2nd quintile	1.41	-0.45	-0.28
3rd quintile	-0.46	-2.31	-2.16
4th quintile	-0.94	-2.90	-2.96
5th quintile	0.11	-1.95	-2.21

Graph 1: Employment effects in the 'Labour market policy' scenario

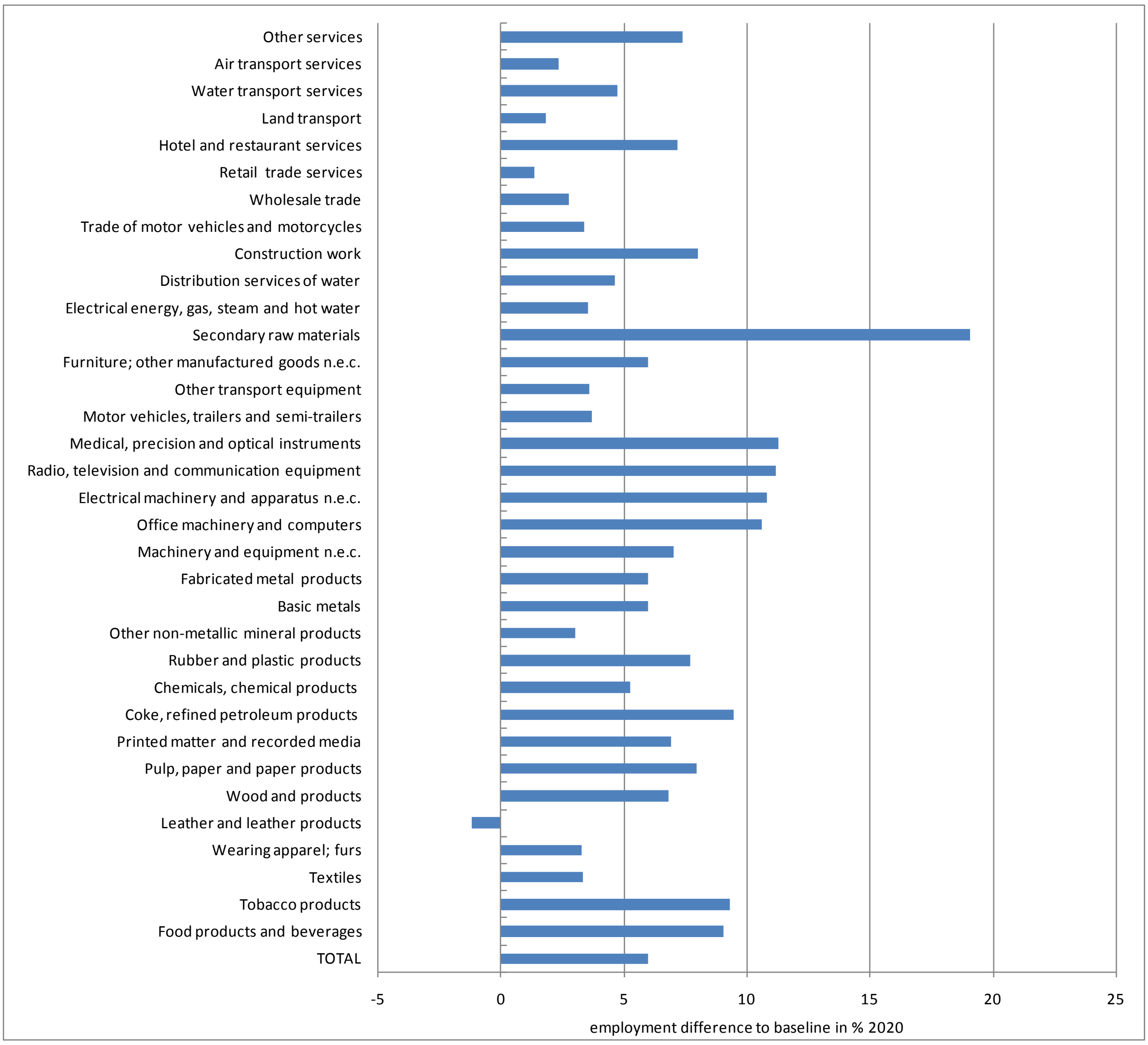


Table 15: Aggregate effects in the 'Environmental fiscal devaluation' scenario (difference to baseline)

	2015	2020	2030
GDP, const. prices	2.58	4.19	5.89
Private Consumption, const. prices	-0.06	-0.12	-0.52
Capital formation, const. prices	0.01	0.02	0.01
Exports, const. prices	1.44	2.19	2.40
Employment (persons)	2.68	4.41	5.85
Unemployment (persons)	-9.68	-16.75	-36.12
Unemployment rate (% points)	-2.10	-3.49	-5.04
GHG emissions, households	-1.64	-1.69	-0.15
GHG emissions, production	-0.70	-1.59	-3.32
GHG emissions, total	-0.87	-1.61	-2.93

Table 16: Income and consumption effects in the 'Environmental fiscal devaluation' scenario (difference to baseline)

	2015	2020	2030
Durable consumption, const. prices	0.74	1.07	1.16
Nondurable consumption, const. prices	0.00	0.00	-0.01
Energy, const. prices	-0.23	-0.36	-0.38
Real disposable income	2015	2020	2030
Total	0.63	1.06	1.40
1st quintile	2.44	1.38	0.20
2nd quintile	1.46	1.01	-0.04
3rd quintile	0.37	0.61	0.65
4th quintile	-0.21	0.26	0.60
5th quintile	0.73	1.54	2.39

Graph 2: Employment effects in the 'Environmental fiscal devaluation' scenario

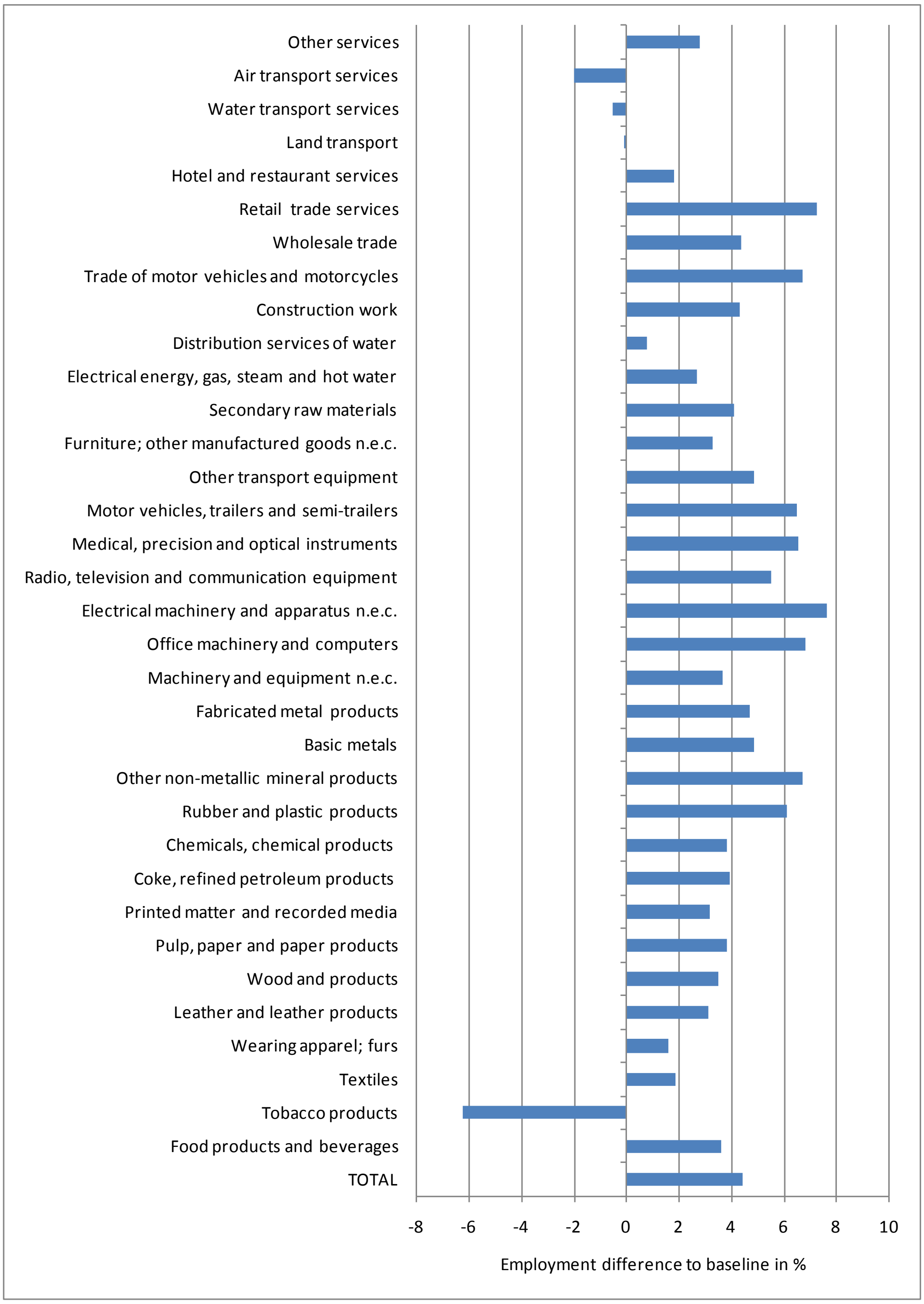


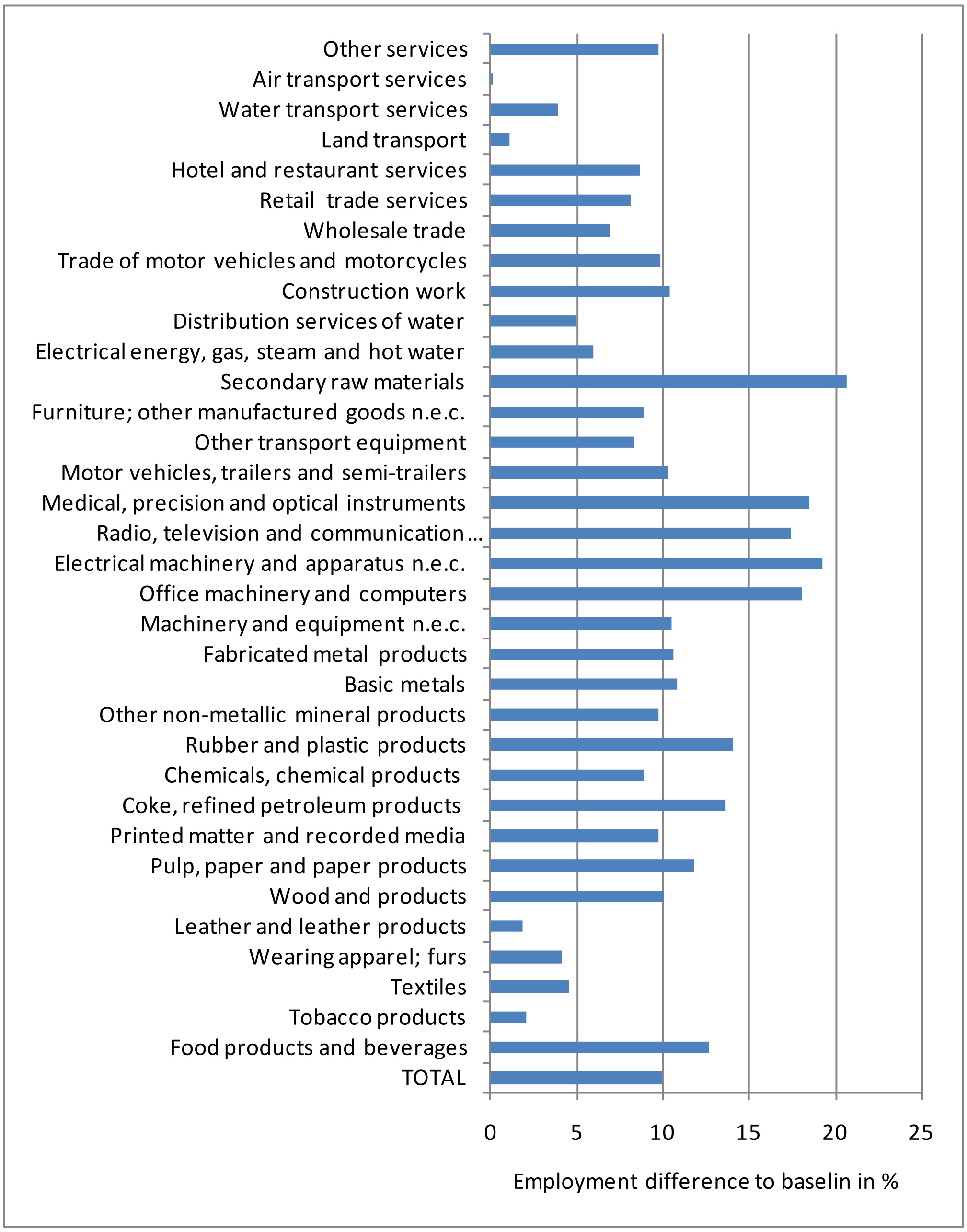
Table 17: Aggregate effects in the 'Combined policy' scenario (difference to baseline)

	2015	2020	2030
GDP, const. prices	3.31	0.21	0.40
Private Consumption, const. prices	-0.04	-2.33	-3.00
Capital formation, const. prices	0.03	-0.02	-0.04
Exports, const. prices	1.57	-1.14	-1.79
Employment (persons)	9.74	9.99	8.97
Unemployment (persons)	-35.23	-37.99	-55.37
Unemployment rate (% points)	-7.63	-7.91	-7.72
GHG emissions, households	-1.81	-2.19	-1.47
GHG emissions, production	-0.52	-3.10	-5.30
GHG emissions, total	-0.76	-2.96	-4.83

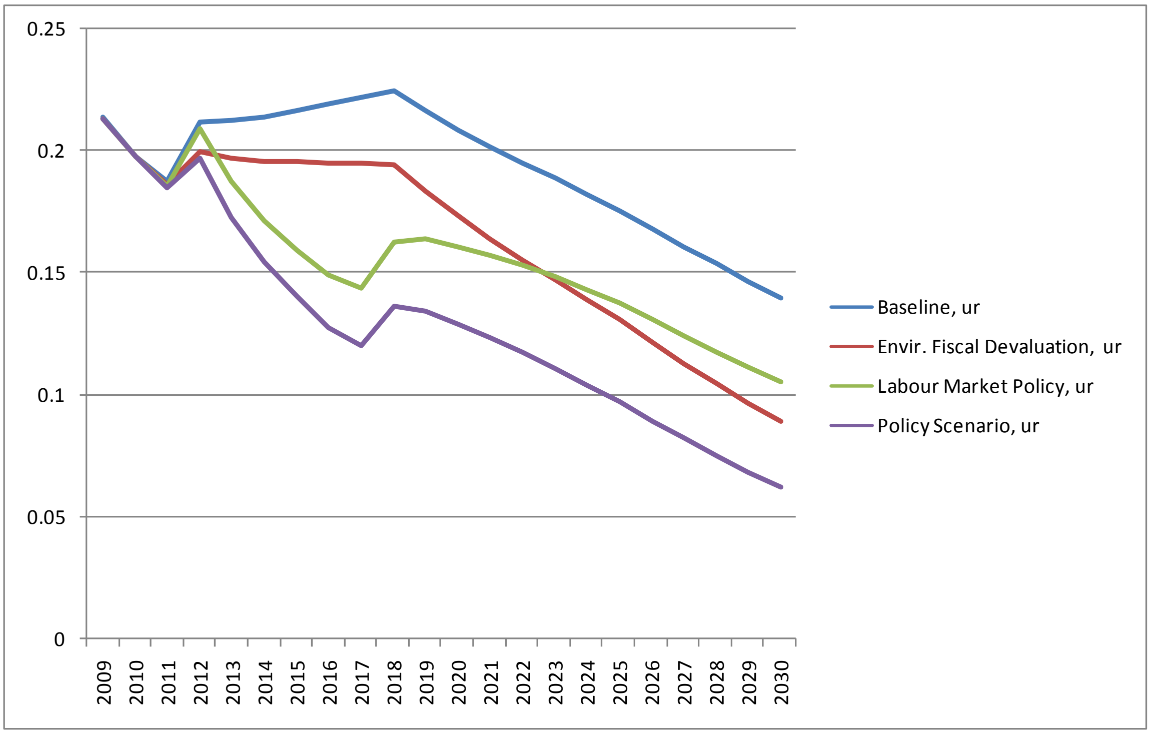
Table 18: Income and consumption effects in the 'Combined policy' scenario (difference to baseline)

	2015	2020	2030
Durable consumption, const. prices	1.16	-0.48	-0.62
Nondurable consumption, const. prices	0.00	-0.03	-0.04
Energy, const. prices	-0.28	-0.59	-0.54
Real disposable income	2015	2020	2030
Total	0.47	-1.09	-0.84
1st quintile	0.12	-2.26	-2.51
2nd quintile	0.71	-1.61	-2.52
3rd quintile	-0.24	-1.89	-1.72
4th quintile	-0.38	-1.91	-1.64
5th quintile	1.08	-0.26	0.27

Graph 3: Employment effects in the 'Combined policy' scenario



Graph 4: Unemployment rate (Spain), in the four scenarios



Graph 5: GDP (Spain), in the four scenarios