Modeling Growth, Distribution, and the Environment in a Stock-Flow Consistent Framework

Policy Paper no 18

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Modeling Growth, Distribution, and the Environment in a Stock-Flow Consistent Framework*

Asjad Naqvi†

February 6, 2015

WORKING PAPER

Abstract

Economic policy in the EU faces a trilemma of solving three challenges simultaneously – growth, distribution, and the environment. In order to assess policies that address these issues simultaneously, economic models need to account for both sector-sector and sector-environment feedbacks within a single framework.This paper presents a multi-sectoral stock-flow consistent (SFC) macro model where a demand-driven economy consisting of multiple institutional sectors – firms, energy, households, government, and financial – interacts with the environment. The model is calibrated for the EU region and five policy scenarios are evaluated; low consumption, a capital stock damage function, carbon taxes, higher share of renewable energy, and technological shocks to productivity. Policy outcomes are tracked on overall output, unemployment, income and income distributions, energy, and emission levels. Results show that investment in mitigation technologies allows for absolute decoupling and ensures that the above three issues can be solved simultaneously.

Keywords: ecological macroeconomics, stock-flow consistent, growth, distribution, environment, European Union

JEL: E12, E17, E23, E24, Q52, Q56

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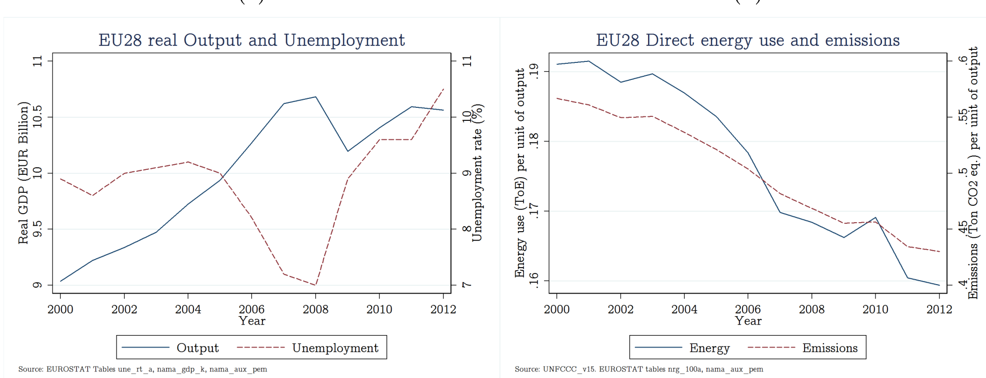
1 Introduction

After the 2008 financial crisis, real output in the European Union (EU) has stagnated while unemployment has crossed the 10% mark (Figure 1.1a). This raises important challenges in addressing issues of inequality and the burden on the welfare state that is set up to ensure a minimum standard of living (European Commission 2014a). The EU is large fairly closed economy, 90% of total output is consumed within its boundaries with almost 60% of it attributed to household consumption (1.3). Thus any form of demand creation will result in alleviating to some extent both the growth and the unemployment issue. However, output and energy use are also highly correlated (Figure 1.1b), implying that any increase in demand will increase energy consumption and emissions, a phenomenon referred to in literature as the "rebound effect" (Binswanger 2001; Jackson 2009; Wiedmann et al. 2013). In light of this, the recently proposed 2030 Kyoto targets of reducing emissions by 40% with a 27% renewable energy becomes an ambitious outcome especially if growth, low employment, and equity are also to be addressed simultaneously (European Commission 2014b, p. 19). Thus if the EU is to achieve its energy targets, absolute decoupling (Jackson 2009) becomes a necessary condition while growth and employment have to accommodate structural adjustments to the economic setup (Foley and Michl 1999; Taylor 2004). In short, the macro level policy challenge for the EU can be abstracted to a growth-distribution-environment trilemma that needs to be solved simultaneously (Kronenberg 2010; Spash 2012; Fontana and Sawyer 2013).

Figure 1.1: EU macro indicators

(a) (b)



In order to address the above issues, a multi-sector macro model is developed in this paper in a stock-flow consistent (SFC) demand driven framework (Godley and Lavoie 2007; Lavoie 2009; Caverzasi and Godin 2013) with supply side environmental constraints (Kronenberg 2010; Fontana and Sawyer 2013). The SFC framework represents a closed monetary economy where different sectors interact endogenously through behavioral decision making rules to generate economic activity while also satisfying double entry accounting principles (Taylor 2004; Godley

Figure 1.2: EU GDP Composition

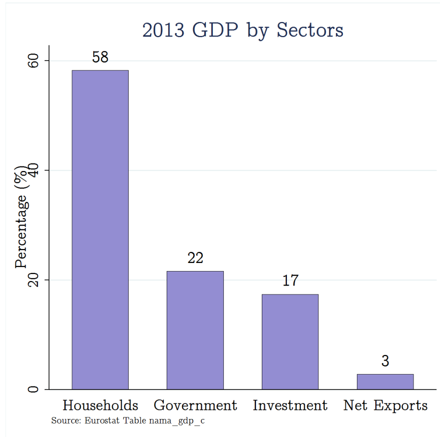


Figure 1.3: By sectors

and Lavoie 2007; dos Santos and Zezza 2008). This implies that the inflow of one sector has to be exactly matched by the outflow of another in a fully tractable monetary system. Stocks represent the net worth of sectors at discrete time periods (for example one year) while flows represent all transactions between two time periods. This water-tight framework ensures flows are not generated in a vacuum but are carefully tracked across all sectors of the economy in a fully tractable closed economic framework. Tables B.1 and B.2 give an example of the stocks and flows of the household sector in the European Union for a one year time period. A key advantage of this framework is that the impact of policies can be tracked across all sectors of the economy. This allows for capturing all positive and negative feedback effects that might result in counter-intended policy outcomes. While recent applications of SFC models have mostly been used to understand sectoral imbalances in the wake of the recent of financial crisis (dos Santos and Zezza 2008; Le Heron and Mouakil 2008; van Treeck 2009; dos Santos and e Silva 2009; Chatelain 2010; Kinsella and Khalil 2011), some efforts have been made to integrate economic issues with environmental constraints (Godin 2012; Berg et al. 2015).

The paper proposes two key innovations in the ecological economics modeling literature. First, it endogenizes the relationship of multiple sectors in the economy within a single framework. This implies that interactions among the firms, energy sector, households, the government, and the financial sector are fully captured which allows for incorporating cross-sectoral feedbacks of various policies. This approach deviates from the other models which exclusively focus on output and growth without fully addressing issues of unemployment and distribution. Second, the model endogenizes the relationship of the real economy and the environment. This is captured through material flows that directly impact the real economy through resource extraction costs and emissions that accumulate in the environment and can affect capital stock and output. This is a deviation from conventional environmental models which discuss the environment damage as an exogenous negative externality that can be solved through market-based pricing (Stern 2007; Weitzman 2009; Yohe et al. 2009; Hope 2011; Pindyck 2013), calculating social costs of carbon (Nordhaus 2011; Pindyck 2013; Foley et al. 2013), or through carbon taxes (Herber and Raga 1995; Marron and Toder 2014). Thus agents are allowed to damage the environment as long as they can afford to pay the monetary cost without fully addressing planetary boundaries (Rockström et al. 2009).

Within a non-mainstream framework, several models have emerged in recent years that aim to address the issues of the impact of climate on the economy and vice versa. These have significantly contributed to topics including building a "sustainable growth" friendly financial sector (Fontana and Sawyer 2014), modeling emissions using an endogenous growth theory with business cycles (Taylor and Foley 2014), modeling environmental damage as an endogenous global negative externality (Rezai et al. 2012), setting up a "green" sector with guaranteed full employment (Godin 2012), linking households financial portfolio decisions with environmental indicators (Victor and Jackson 2013), and combining input-output material flows with the prices and interest rates in a stock-flow consistent framework (Berg et al. 2015). This model contributes to these class of models by providing a complete economic and environment accounting framework for the production, or the "real-real" side, of the economy that allows for policy tracking. Thus in the model, the focus is kept directly on production decisions and household demand formation while a very simple financial sector is introduced. This keeps the model simple and tractable while also focusing on direct household related issues including employment, real income levels and functional income distributions.

Five policy experiments proposed in the ecological economics literature are conducted on a model calibrated to the EU economy. The first experiment looks at a de-growth scenario based on the "limits to growth" hypothesis (Meadows and Club of Rome 1972; Jackson 2009; Victor 2012). This hypothesis suggests that policy driven reduction in output will result in lower energy use and subsequently lower emissions. The second experiment introduces a damage function that endogenizes the depreciation of capital stock to the level of emissions (Tol 2002; Stern 2007; Hope 2011; Nordhaus 2011; Rezai et al. 2012). This . The third experiment highlights the costs of shifting to a higher share of low-emissions high-cost renewable energy (Trainer 1995; Dincer 2000; Tahvonen and Salo 2001; Varun et al. 2009). The fourth experiment introduces carbon taxes on firms and households (Herber and Raga 1995; Marron and Toder 2014). The fifth experiment discusses technological innovation and resource efficiency that aims to address issues of growth in an absolute decoupling scenario (Binswanger 2001; Yang and Nordhaus 2006; Herring and Roy 2007). The model outputs track output and growth with other key macroeconomic indicators including unemployment, income and income distributions, prices, energy, and emissions.

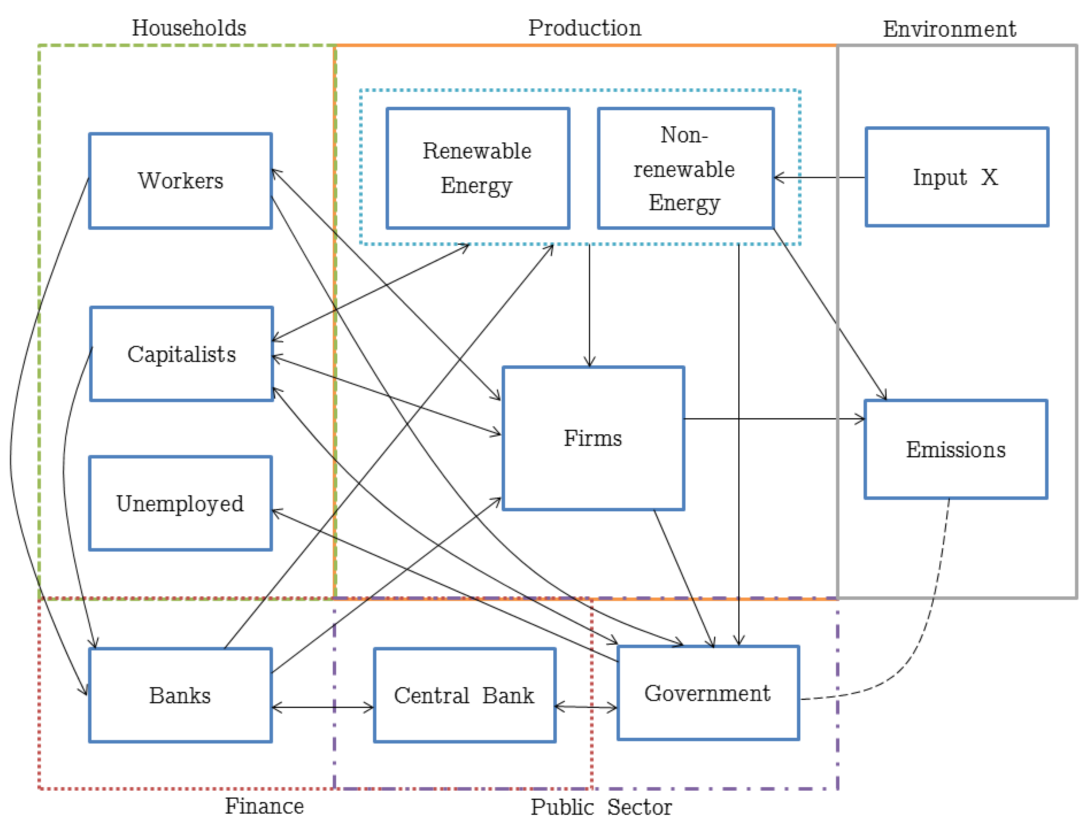
The paper is organized as follows. Section 2 sets up the framework and Section 3 explains the model in detail. Section 4 describes policy scenarios and the simulation results. Section 5 concludes. Behavioral equations of the financial sector are discussed in Appendix D.

2 Framework

Figure 2.1 summarizes the relationships between four economic sectors in the model – production, households, government, and the finance sector - and one environment sector. The production sector is taken as a macro institution that produces both capital and consumption goods where output is determined through demand by household consumption, government expenditure, and firm investment. This demand generation is supported by banks in the form of deposits, loans and advances to form a complete circular flow economy. The production process requires three complimentary inputs; capital, labor, and energy. Capital is generated through investment, worker households provide labor, while energy is supplied by energy producers.This allows the firms and the energy sector to be dual-linked through energy demand and prices. Energy supply is generated from an exogenously determined mix of non-renewable and renewable energy.

The real economy is integrated with the environment through two channels. First, energy production requires a non-renewable input that depletes over time and second, Greenhouse Gas (GHG) emissions, generated through the production process, accumulate in the atmosphere.

Figure 2.1: Model layout



In order to account for differences in the functional income distribution, two household classes are introduced in the model. Capitalists, as owners of capital (firms, energy, banks)who earn profit income and workers as owners of labor who earn wage income if employed or unemployment benefits if unemployed. Real disposable income determines consumption levels while savings are kept in commercial banks. Commercial banks give out loans to the Production sector. If demand for loans exceed deposits, Commercial banks can request advances from the central bank which results in the creation of endogenous money (Moore 1988; Starr 2003; Keen 2014; Lavoie 2014a). The government earns tax revenue from firms, households and the financial sector which it uses to fund public sector investment and unemployment benefits. If a deficit exists, it is financed by issuing short-term Treasury Bills.

Following the accounting framework presented in Godley and Lavoie (2007), economic activities are tracked in two monetary accounts, a balance sheet and a transition flow matrix (TFM). The balance sheet is given in Table A.1 where the columns show the net worth of the economy across different institutional sectors at the end of each of a time period. Interactions between agents results in flows between two time period which are summarized in the transition flow matrix in Table A.2. Double entry accounting restrictions imply that all rows and columns must add up to zero. Columns represent the sources and uses of funds for each agent category. For example, the worker's column in the TFM shows wages and interest earnings on deposits as inflows while taxes and consumption are outflows. Savings results in changes in bank deposits which are also reflected as change in the balance sheet. As an example, Appendix B shows how stocks and flows for the household sector evolve in the EU over a one year period.

3 Model

This section gives the behavioral rules of the agent categories using the following system of notations; capital letters are used to represent nominal (current) value in money while lowercase letters represent real values or stocks. For different agent categories, the same variables are super-scripted using h for workers, k for capitalists, u for unemployed, f for firms, X for non-renewable energy, R for renewable energy, b for commercial banks, CB for the central bank, and g for government. Time is denoted with a subscript t and exogenous parameters are written using Greek symbols. Δ represents a first order difference.

3.1 Firms

The firms sector in the model produces both consumption and capital goods based on demand from households, government and the production sector's investment decisions. Assuming full information about current demand with adaptive expectations, the firm's total real output y_t equals total sales s_t plus changes in stock of inventories in_t (3.1).

$$
\begin{aligned}
y_t &= s_t + \Delta in_t && (3.1)\\
s_t &= \left(c_t^k + c_t^h + c_t^u\right) + \left(i_t + i_t^X + i_t^R\right) + \Omega && (3.2)\\
\Delta in_t &= \gamma(\sigma s_{t-1} - in_{t-1}) && (3.3)
\end{aligned}
$$

Total sales are calculated as the total consumption demand by households (capitalists, workers, unemployed), investment decisions of the firms and the two energy sectors plus the governments autonomous expenditure Ω. Change in inventories, Δin_t are determined as a fraction γ of the gap between target inventories, determined as ratio σ of past sales, minus inventories at the start of the period. Firms hold inventories to hedge against any unexpected changed in demand.

The production process requires three complimentary inputs; labor, capital and energy. The demand for labor N_t^f is determined by total output produced over the exogenously defined labor productivity per unit of output ξ^{YN}. The total wage bill (3.5) is calculated as total workers hired times the exogenous wage rate ω.

$$
\begin{aligned}
N_t^f &= \frac{y_t}{\xi^{YN}} && (3.4)\\
WB_t &= N_t^f.\omega && (3.5)
\end{aligned}
$$

Similar to labor demand, energy demand is determined by total output over the capital-to-energy productivity ratio ξ^{YE} (3.6). The total energy bill is determined as the total energy demand times the price of energy p_t^E (3.7).

$$
\begin{aligned}
E_t &= \frac{y_t}{\xi^{YE}} && (3.6)\\
EB_t &= E_t.p_t^E && (3.7)
\end{aligned}
$$

Firms actual capital stock in use to produce output is determined by the capital-to-output ratio ξ^{YK}

$$
k_t = \frac{y_t}{\xi^{YK}} \qquad (3.8)
$$

Firms, as part of their liquidity preference strategy, keep a certain proportion of their capital stock slack in order to adjust to changes in demand. The decision to invest in capital stock is determined through an accelerator function (Jorgenson 1963; Taylor 2004; Storm and Naastepad 2012; Lavoie 2014b) driven by the target capacity utilization ratio ν. Actual investment i_t is determined by two parameters; capital depreciation rate δ, and the rate of investment β, and the gap between current capacity utilization rate u_t and the target capacity utilization rate ν.

$$i_t = \text{Max}[\beta(u_t - \nu) + \delta, 0]k_{t-1} \quad (3.9)$$

The value of the investment i_t (3.9) is bounded below by zero implying that negative investment in capital is not allowed. The expression in equation 3.9 gives three investment regions; firms increase capital stock if demand increases ($u_t > \nu$), firms invest to maintain at least the depreciation value $i_t = \delta$ of capital stock if demand doesn't change ($u_t = \nu$), and firms don't invest at all ($i_t = 0$) if demand goes down and capital is under utilized. In this scenario, capital stock is allowed to depreciate in value.

Current capacity utilization (3.10) is described as the current output divided by maximum potential output $\bar{y}_t$.

$$u_t = \frac{y_t}{\bar{y}_t} \quad (3.10)$$

$$\bar{y}_t = \xi^{YK} k_{t-1} \quad (3.11)$$

Assuming firms are fully leveraged and money is readily available from commercial banks, the current nominal value of loans requested by firms equals the nominal value of expected change in inventories $\Delta IN_t = UC_t \Delta in_t$ and the nominal value of capital stock investment $I_t = i_t p_t$. Thus the demand for loans can be written as:

$$L_t^f = I_t + \Delta IN_t \quad (3.12)$$

$$R_t^f = \lambda L_{t-1} \quad (3.13)$$

Every time period, a fraction λ of past loans is repaid to the banks.

From equations 3.5, 3.7 and 3.13, the unit cost per unit of output can be derived as:

$$UC_t = \frac{WB_t + EB_t + R_t^f}{y_t} \quad (3.14)$$

$$p_t = UC_t(1 + \theta)(1 + \tau_F) \quad (3.15)$$

Prices are determined through an exogenous markup θ over unit costs and the tax rate τ_F. Thus an increase in wages, energy prices and loans would add to the costs and subsequently prices within the economic system feeding back on demand.

Firms realized profits thus equal:

$$\Pi_t^f = S_t(1 - \tau_F) + \Delta IN_t - WB_t - EB_t - R_t^f - (r_l L_{t-1}^f) \quad (3.16)$$

where the first term above gives the nominal value of sales $S_t = s_t p_t$ minus taxes. The last term represents the interest paid to commercial banks based on past loans. The profits are fully redistributed to the capitalists.

3.2 Energy Sector

The energy sector supplies uniform energy to firms produced through two sources. A non-renewable input dependent high emissions energy and a zero emissions renewable resource dependent capital intensive energy. The share of non-renewable energy in total supply is exogenously determined by the parameter ϕ. The energy sector mirrors the production sector with two key exceptions. First, the energy sector's investment decision to expand production capital adds to the demand of the firms. Second, the energy sector has an endogenous own energy consumption cost to produce energy demanded by firms.

Non-renewable energy production requires a non-renewable input X, a resource that has to be extracted from the environment. The quantity of X required to meet this demand, or indirect sales of X to firms is given as:

$$s_t^X = \frac{\phi E_t}{\xi^{XE}} \tag{3.17}$$

where ξ^{XE} is the X-to-non-renewable energy ratio. In order to produce energy the non-renewable sector requires to consume energy as well. Total output of X is given as:

$$y_t^X = s_t^X(1 + \eta^X)$$

where η^X is the share of energy required for own consumption.

Assuming energy cannot be stored, the energy sector holds inventories of the non-renewable input X to smooth out unexpected changes in energy demand. The stock of X extracted every time period is given as:

$$X_t = y_t^X + \Delta in_t^X \tag{3.18}$$

or the total sales plus changes in inventories of X determined by the inventories to sales ratio σ following the same procedures as defined for firms in equation 3.3.

The non-renewable energy sector faces two costs: an extraction cost determined per unit of output as κ^X and the own cost of consumption determined as a fraction η of total sales.

$$XC_t = \kappa^X . X_t \tag{3.19}$$

$$OC_t^X = \eta^X s_t^X \tag{3.20}$$

From this the unit cost for the non-renewable energy sector can be derived as:

$$UC_t^X = \frac{XC_t + OC_t^X}{y_t^X} \tag{3.21}$$

For the renewable energy sector, the total demand equals the total share of energy output produced by the renewable sector.

$$s_t^R = (1-\phi)E_t^f \tag{3.22}$$
$$y_t^R = s_t^R(1+\eta^R) \tag{3.23}$$

The total output produced is a fraction η^R of total demand to accommodate own consumption. For simplicity we assume that the only cost renewable energy sector faces is its own cost of consumption given as:

$$OC_t^R = \eta^R s_t^R \tag{3.24}$$
$$UC^R = \frac{OC_t^R}{y_t^R} \tag{3.25}$$

In order to ensure that the renewable energy sector is more expensive than the non-renewable sector own costs in the renewable energy sector are higher than those of the non-renewable sector such that $\eta^R > \eta^X$.

The price of energy, p_t^E is derived as follows:

$$p_t^E = \left(\phi UC_t^X(1+\tau^X) + (1-\phi)UC^R(1+\tau^R)\right)(1+\theta) \tag{3.26}$$

This is a simple weighted average of the unit cost adjusted for energy sector industry specific taxes, τ^X and τ^R times the fixed mark-up θ. Assuming $\eta^R > \eta^X$ (3.26) implies that as the share of renewable energy in total energy supply goes up, the price of energy will increase as well. Profits from both non-renewable and renewable, Π_t^X and Π_t^R are fully redistributed to the capitalists.

3.3 Environment

The environment is introduced in the model as providing the non-renewable resource $\bar{X}$ through extraction from the ground and as absorbing Greenhouse Gases (GHGs) in the atmosphere. The resource depletion rate RD_t of the non-renewable input is already defined in 3.27

$$RD_t = \frac{\bar{X}}{\bar{X} - \sum_{i=0}^{t-1} X_i} \quad (3.27)$$

$\bar{X}$ is the quantity of the finite stock of non-renewable input while the denominator gives the current value of the non-renewable input left in stock. The function implies that extraction costs have a negligible impact on prices if a relatively small proportion of the non-renewable resource has been extracted. Costs increase exponentially as $\bar{X}$ nears depletion. This extreme condition is not explicitly discussed in this paper.

GHGs are assumed to accumulate at a linear rate relative to the level of firm production and of high emission energy sector production. The increase in stock is formalized as:

$$GHG_t = GHG_{t-1}(1 - \phi) + \frac{y_t + y_t^X}{\xi^{YG}} \quad (3.28)$$

where ϕ is an exogenously defined parameter representing the absorption capacity of GHG into the environment or the natural carbon cycle (IPCC 2007, 2012). ξ^{YG} is the emissions-to-output ratio indexed to a baseline value.

3.4 Households

Households are composed of capitalists and workers. In the model, all household agent categories are assumed to follow the same decision making procedures. The key difference lies in the income source:

$$Inc_t^k = \Pi^f + \Pi_t^X + \Pi_t^R + \Pi_t^b + r_d D_{t-1}^k \quad (3.29)$$

$$Inc_t^h = WB_t + r_d D_{t-1}^h \quad (3.30)$$

$$Inc_t^u = UB_t \quad (3.31)$$

Capitalists earn profit income from the production and financial sector plus interests on bank deposits (3.29). Employed workers earn wages plus interest income from deposits (3.30), while the unemployed households receive transfers from the government (3.31).

Given a total fixed labor force of $\bar{N}$, unemployed households are simply workers not employed by the firm sector (3.32).

$$N^u = \bar{N} - N_t^f \quad (3.32)$$

$$ub_t = N^u.\epsilon \quad (3.33)$$

The unemployed households N^u are expected to maintain a socially defined minimum level of consumption ϵ in the form of unemployment benefits ub_t (3.33) where the nominal value of the transfer program is given as:

$$UB_t = ub_t.p_t \tag{3.34}$$

Household income after tax τ_h gives the disposable income as follows:

$$YD_t = Inc_t(1 - \tau_h) \tag{3.35}$$

Households make consumption decisions based on real income and wealth levels. The consumption decision in real terms is defined as:

$$c_t = \alpha_1 yd_{t-1} + \alpha_2 v_{t-1} \tag{3.36}$$

where yd_t and v_t are real values of disposable income and wealth, and α_1 and α_2 are the marginal propensities to consume out of income and wealth respectively. Disposable income net of consumption results in a change in nominal wealth:

$$\Delta V_t = YD_t - C_t \tag{3.37}$$

All savings after tax and consumption are deposited in banks which gives the net worth of the households.

$$D_t \quad = \quad V_t \tag{3.38}$$

3.5 Government

The government plays two important roles in the model. First it is required to make consumption expenditures to maintain social infrastructure and investment. Government consumption is defined exogenously as Ω which in nominal terms equals

$$G_t = \Omega.p_t \tag{3.39}$$

Second, it ensures a minimum consumption level for the unemployed such that the total unemployment benefits bill is UB_t (3.34). This expenditure is financed through tax revenues that it earns from the firms and the households where the total taxes collected equal:

$$Tax_t = T_t^f + T_t^X + T_t^R + T_t^k + T_t^h \tag{3.40}$$

If the tax revenue is not sufficient to finance the government expenditure then the government issues treasury bills, TB_t. The government's debt or borrowing requirement BR_t is defined as:

$$BR_t = G_t + UB_t + r_b TB_{t-1} - Tax_t - \Pi_t^{CB} \quad (3.41)$$

$$\Delta TB_t = BR_t \quad (3.42)$$

where $r_b TB_{t-1}$ is the interest owed on past treasury bills issued and Π_t^{CB} are central bank profits redistributed to the government. New treasury bills issued equal the government debt requirement (3.42). In the model all bills are assumed to be purchased by the central bank and thus central bank profits include interest earnings on advances to commercial banks and treasury bills (see Appendix D).

4 Policy experiments

Five key policy experiments derived from the literature are discussed here and compared with a Business-As-Usual (BAU) scenario calibrated using parameters broadly estimated for the EU from publicly available databases or literature (Appendix C). Household parameters in the EU are derived from two micro-datasets, the EU-SILC and the HFCS, that provide detailed information on classes and wealth levels (recent studies include Wolff and Zacharias 2013; Carroll et al. 2014). Banking and lending information is available at the European Central Bank's Statistical Warehouse with detailed breakdown of tax and interest rates. Parameters defined in equations using post-Keynesian assumptions have been derived from a long history of empirically verified hypotheses that are neatly summarized in Godley and Lavoie (2007). The innovation parameters (ξ) have been normalized and index to 1 to allow for comparisons to the BAU scenario but can be extended to actual levels using the EU-KLEMS or WIOD datasets. Remaining parameters are estimated from the Eurostat database.

The aim of these experiments is to track the impact of policies on total output, prices, level of unemployment, capitalist and worker incomes, energy demand and emission levels.

- *Reduction in consumption expenditure (LowCon):* The literature on low or no-growth (Jackson 2009; Victor 2012; Victor and Jackson 2013) claims that reducing demand will result in a reduction of output and income levels and emissions. In this experiment government and household consumption is reduced by 10%.
- *Damage function (DmgFunc):* Following the literature on damage function (Nordhaus 1992; Tol 2002; Wahba and Hope 2006; Stern 2007; Hope 2011; Rezai et al. 2012; Pindyck 2013; Taylor and Foley 2014), emissions levels beyond a certain threshold φ are assumed to result in a higher depreciation rate of capital stock. For this experiment, the depreciation

rate of δ is endogenized as follows:

$$\delta_t = \delta \left(1 + Max\left[\frac{GHG_t - \varphi}{\varphi}, 0\right]\right)$$

where φ is the emissions threshold given in parts per million by volume (ppmv) beyond which emissions are assumed to damage capital stock.

- *High share of renewable energy (HiRenew):* The innovation literature suggests a shift towards renewable energies (Trainer 1995; Dincer 2000; Tahvonen and Salo 2001; Varun et al. 2009) for environmentally sustainable growth. This experiment increases the share of renewable energy by 10% in total energy consumption. The aim of this experiment is to test the output and distributional impacts of switching to a cleaner but more expensive technology.

- *Environmental tax on firms and households (TaxF and TaxH):* The endogenous environmental tax follows a similar logic as the damage function (Herber and Raga 1995; Marron and Toder 2014). The government increases the tax relative to the level of targeted emissions φ.

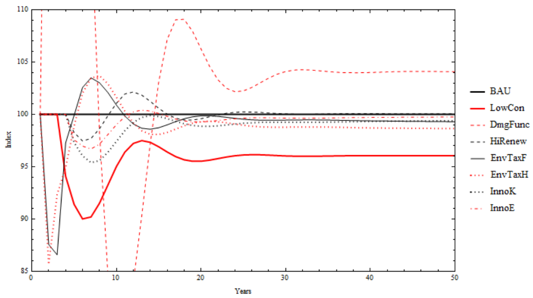
$$\tau_t = \tau \left(1 + Max\left[\frac{GHG_t - \varphi}{\varphi}, 0\right]\right) \tag{4.1}$$

  As emissions increase beyond this threshold, taxes rise at an exponential rate feeding back across the system through a reduction in demand. Two policy experiments that are conducted are an endogenous profit tax on firms and an endogenous income tax on households.

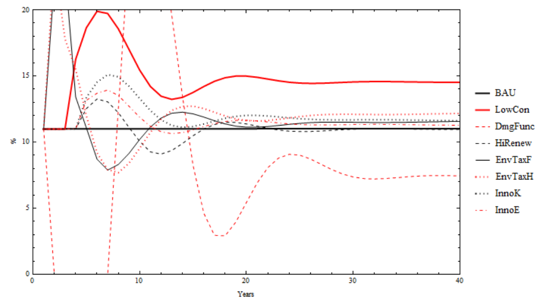
- *Capital and Energy efficiency (InnoK and InnoE):* Capital and energy efficiency increases output without increasing direct input costs (Binswanger 2001; Yang and Nordhaus 2006; Herring and Roy 2007). In the BAU scenario, the capital-to-output ratio ξ^{YK} and the energy-to-output ratio ξ^{KE} are normalized and indexed to 1. In this experiment, both the parameters are shocked exogenously resulting in an increase in efficiency by 10% respectively. A value of $\xi^{YK} = 1.1$ implies that lower capital is required to produce the same level of output while a value of $\xi^{KE} = 1.1$ implies less energy is required per unit of output.

Figure 4.1: Policy Experiments

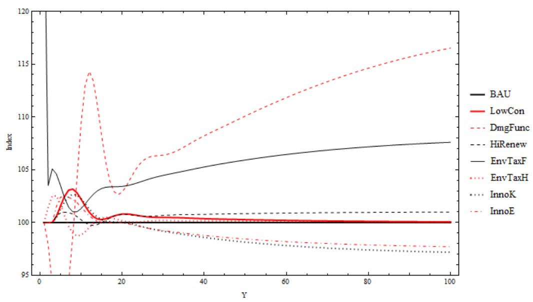
(a) Real output



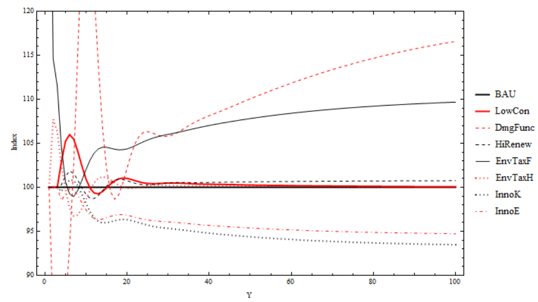
(b) Unemployment rate



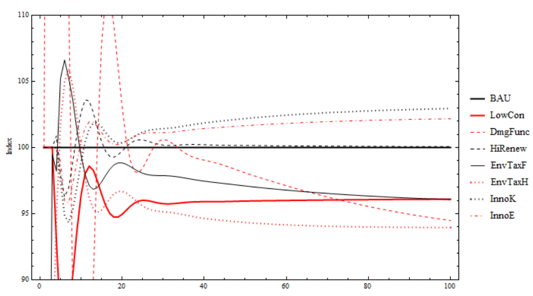
(c) Price of E



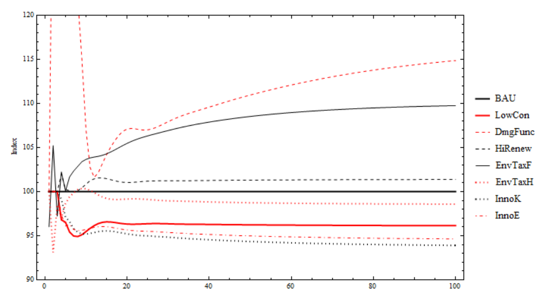
(d) Price of Y



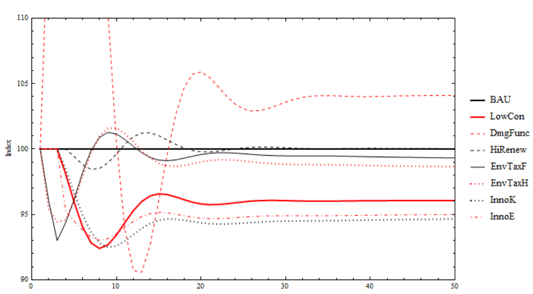
(e) Real disposable income



(f) Capitalist-Worker functional income distribution



(g) Energy demand



(h) GHG emissions

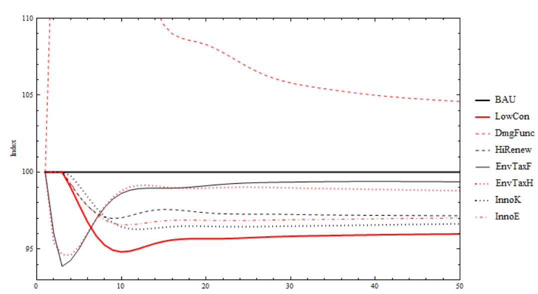


Table 4.1: Summary of policy experiments

	Growth		Distributions		Environment	
	Output	Unemp.	Real Income	Func. Income Dist.	Energy	Emissions
LowCon	↓	↑	↓	↓	↓	↓
DmgFunc	↑	↓	↓	↑	↑	↑
HiRenew	∼	∼	∼	∼	∼	↓
TaxF	∼	∼	↓	↑	∼	∼
TaxH	∼	∼	↓	∼	∼	∼
InnoK	∼	∼	↑	↓	↓	↓
InnoE	∼	∼	↑	↓	↓	↓

Note:∼within 2% of BAU, ↑more than 2% increase, ↓more than 2% decrease. Functional income distribution calculated as capitalist/worker income.

The experiments are described in Figure 4.1. Figures 4.1a and 4.1b show that almost all simulations roughly stabilize to the pre-shock BAU level of output and unemployment, with the exception of the *LowCons* and the *DmgFunc* experiments. Whereas the lower output in the *LowCons* case is due to the postulated reduction in consumption expenditure and thus demand, the *DmgFunc* experiment results – counter-intuitively – in higher output. This is due to the fact that increasing the depreciation of capital raises the investment requirement for firms. Since investment is part of final demand and credit financing is available due to endogenous money, output rises and unemployment decreases.

Table 4.1 summarizes the results for all the experiments. It shows that neither the link between output and distribution, nor the one with the environment is predetermined. In particular, while the connection between output and unemployment conforms to the standard formulation of Okun's law, the income level and the functional income distribution are not as clear-cut. Regarding environmental aspects, the absolute decoupling of energy use and emissions from output can be observed in this model in some cases.

The lower output in the low consumption scenario *(LowCons)* case coincides with higher unemployment and lower incomes, but also lower energy consumption and reduced emission, as expected. It also leads to a lower inequality between capital and labor income as a result of lower profit margins for capitalists that decline more than the wages.

The higher output resulting from higher investment in the endogenous damage function *(DmgFunc)* experiment is accompanied by lower unemployment and higher energy use and more greenhouse gas emissions. It also goes along with lower real disposable income and lower worker income relative to capitalist income, which are a result of the price dynamics shown in Figures 4.1d and 4.1c. The higher level of loans increases prices as firms push the cost of loan repayment on to the consumers for both energy (through demand) and for final goods (higher financing costs), which leads to the lower real disposable income of households and redistributes away from workers.

In the higher renewables share *(HiRenew)* case, which assumes a switch to renewable energy, leaves output, all three aspects of distribution and energy use are unchanged. Emissions, however, decline, because of the less polluting energy production. A number of minor adaptations accompany the restructuring of the capital stock away from non-renewable energy producers and towards renewable energy production, such as a slight increase in the price of energy and thus of final goods and some redistribution towards capitalists. However, these effects are small, so that the decline in emissions takes place virtually ceteris paribus with regard to the variables investigated here.

An environmental taxing on households (*TaxH*) and firms (*TaxF*) increases with higher GHGs. As a result real disposable incomes declines reducing output. Unemployment rises while energy use and emissions fall slightly below BAU level. The difference between the two experiments lies in the effect on real incomes, which fall more when households are directly taxed as opposed to firms. On the other hand the functional income distribution worsens in the firm tax scenario while improving slightly in the household tax. The underlying causal mechanism can be inferred from the price changes in Figures 4.1d and 4.1c. When firms are taxed (*TaxF*), prices for both energy and final goods rise as the tax burden is passed on to consumers. As a consequence, real incomes fall in the *TaxF* experiment but less than in the *TaxH* experiment. Thus capitalists partially increase the demand for goods through higher profits subsequently worsening the functional income distribution while keeping the output demand relatively close to BAU level.

The final two experiments, innovation in capital (*InnoK*) and energy efficiency (*InnoE*), reduce both energy demand and emissions while maintaining a stable output and stable unemployment. At the same time, real incomes rise and the ratio of capitalist to worker disposable income falls. These experiments thus come closest to the "hat trick" of scoring on all three fronts: output, distribution and environment. The dynamics behind this result are the following: The *InnoK* simulation lowers the capital required for goods production, and thus indirectly the energy demand. The *InnoE* scenario shows similar outcomes although the transmission mechanism is a simple price adjustment process resulting from a decline in energy costs.

5 Conclusions

This paper is motivated by the trilemma of growth, distribution and the environment currently facing European economic policy. It develops a stock-flow consistent macro model of a closed economy, which incorporates supply-side effects into a demand-driven model. The model encompasses all sectors of the economy. Two innovations are introduced: first, energy production is formulated in more detail compared to previous studies and second, the environment is explicitly introduced into the model. The stock-flow consistent framework ensures that accounting principles are maintained and feedback effects across sectors are accounted for.

The model is calibrated to the European economy, and applied to five environmental economic policies typically discussed in the literature. The aim is to assess their effect on the three aspects of output growth, distribution (comprising unemployment and the functional income distribution), and environmental sustainability.

The results show that neither the link between output and distribution, nor the one with the environment is predetermined. In particular, while the connection between output and unemployment conforms to the standard formulation of Okun's law, the income level and the functional income distribution are not as clear-cut. Similar macro level outcomes can be the result of very different underlying structural and distributional changes. Regarding environmental aspects, the absolute decoupling of energy use and emissions from output can be observed in this model in some cases.

In particular, four policies show different trade-offs within the trilemma. The de-growth simulation shows that the lower output leads to higher unemployment while at the same time reducing inequality in the functional income distribution. If emissions feed back into the depreciation of the capital stock as in the damage function experiment, this has the opposite effect: unemployment falls but the functional income distribution worsens for workers. At the same time, this is the only policy which leads to higher emissions due to increased investment requirements. Environmental taxes on households or firms have mainly distributive effects while leaving output and emissions largely unchanged.

Three policies, however, are triple-win situations. Increasing the share of renewable energy reduces emissions while leaving all other outcome variables virtually unchanged. Finally, innovations in capital or in energy productivity reduce both energy use and emissions, while at the same time raising real incomes and redistributing towards workers.

These findings are, of course, to be interpreted with caution as they are derived from a stylized model. However, they may give first pointers in the complex, multi-dimensional policy space in which environmental economic policy is located.

The model presented here can be extended to test for additional climate-related policies while keeping track of the feedback effects. These for example can include endogenous growth, innovation and technical change, and endogenous counter-cyclical government spending. A key area for advancement of this model is the inclusion of aspects of financialization that indirectly feedback into the real economy and subsequently the environment.

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A Macro accounts

Table A.1: Balance Sheet

	Households			Production		Financial		Govt.	$\sum$
	Unemp.	Workers	Capitalists	Firms	Energy	Banks	Central Bank		
Capital stock				$+K$	$+K^X + K^R$				$+K$
Inventories				$+IN$	$+IN^X$				$+INV$
Bank Deposits		$+D^h$	$+D^k$			$-D^b$			0
Advances						$-A^b$	$-A$		0
Bills							$+B^{CB}$	$-B$	0
Loans				$-L^f$	$-L^X - L^R$	$+L$			0
$\sum$	0	$+V^h$	$+V^k$	$+V^f$	$+V^X + V^R$	0	0	$-V^G$	$+NV$

Table A.2: Transition Flow Matrix

	Unemp.	Workers	Capitalists	Firms		Energy		Commercial Banks		Central Bank		Govt.	$\sum$
				Current	Capital	Current	Capital	Current	Capital	Current	Capital		
Consumption	$-C^u$	$-C^h$	$-C^k$	$+S$								$-G$	0
Energy				$-EB$		$+E^X + E^R$							0
Wages		$+WB$		$-WB$									0
Investment				$+I + I^X + I^R$	$-I$		$-I^X - I^R$						0
ΔInventories				$+\Delta IN$	$-\Delta IN$	$+\Delta IN^X$	$-\Delta IN^X$						0
Unemp. Benefits	$+UB$											$-UB$	0
Bank profits			$+\Pi^b$					$-\Pi^b$		$-\Pi^{CB}$		$+\Pi^{CB}$	0
Firm profits			$+\Pi^f$	$-\Pi^f$									0
Energy profits			$+\Pi^E$			$-\Pi^X - \Pi^R$							0
Taxes		$-T^h$	$-T^k$	$-T^f$		$-T^X - T^R$						$+T$	0
i Advances								$-r_a A_{t-1}$		$+r_a A_{t-1}$			0
i Deposits		$+r_d D^h_{t-1}$	$+r_d D^k_{t-1}$					$-r_d D_{t-1}$					0
i Bills										$+r_b B^{CB}_{t-1}$		$-r_b B_{t-1}$	0
i Loans				$-r_l L^f_{t-1}$		$-r_l L^X_{t-1} - r_l L^R_{t-1}$		$+r_l L_{t-1}$					0
ΔAdvances									$+\Delta A$		$-\Delta A$		0
ΔDeposits		$-\Delta D^h$	$-\Delta D^k$						$+\Delta D$				0
ΔBills											$+\Delta B^{CB}$	$-\Delta B$	0
ΔLoans					$+\Delta L^f$		$+\Delta L^X + \Delta L^R$		$-\Delta L$				0
$\sum$	0	0	0	0	0	0	0	0	0	0	0	0	0

B Stocks and flows of the EU household sector

Table B.1: Household Balance Sheet (EUR Billions)

Category		2012-Q4	2013-Q4	Δ
Non financial assets	Non-financial assets	29,625	29,041	-584
	(Housing wealth)	*28,055*	*27,435*	*-620*
Financial assets	Currency and deposits	7,046	7,225	179
	Securities and derivatives	1,537	1,365	-172
	Loans	-6,196	-6,152	44
	Shares and equities	4,310	4,858	543
	Insurance and pension	5,939	6,184	-245
	Other	195	169	-26
	Net worth	**42,456**	**42,685**	**229**

Source: ECB Monthly Bulletin May 2014

Table B.2: Household Flow of funds (EUR Billions)

Flows	**2013-Q4**
Total income (all sources)	7,059
Net social contributions receivable	182
Tax	-962
Gross disposable income	6,279
Consumption	*-5,507*
Gross savings	829
Consumption of fixed capital	-407
Net capital transfers	-4
Change in worth of stocks	-189
Net savings (Δ net worth)	**229**

Source: ECB Monthly Bulletin May 2014

C BAU Parameters and Variables

Parameter	Value	Description	Source
N^k	5%	Capitalists as a % of total population	Wolff and Zacharias 2013
Ω	50%	Baseline government expenditure as percentage of output	Eurostat 2015 Table gov_a_exp
ω	1	Unit labor cost	Eurostat 2015 Table nama_aux_ulc
α_1	0.8	MPC out of income	Eurostat 2015 Table nasa_ki
α_2	0.1	MPC out of wealth	Carroll et al. 2014
β	0.25	Rate of investment in capital stock	Godley and Lavoie 2007
δ	0.05	Rate of depreciation	Godley and Lavoie 2007
ν	0.8	Target capacity utilization ratio	Godley and Lavoie 2007
η	0.05	Own consumption of energy	Eurostat 2015 Table nrg_100a
τ	0.2	Tax rate	Eurostat 2014
σ	0.25	Target inventories to sales ratio	Godley and Lavoie 2007,
γ	0.2	Rate of investment in inventories	Godley and Lavoie 2007,Eurostat 2015 Table nama_10_gdp
θ	0.1	Markup on costs	Gullstrand et al. 2011
ϵ	0.6	Poverty line relative to median income	European Union definition of poverty line
ϕ	0.05	GHG absorption rate	IPCC 2007, 2012
r_l	0.04	Interest on loans	European Central Bank 2015 Monetary and financial statistics
r_d	0.02	Interest on deposits	European Central Bank 2015 Monetary and financial statistics
r_b	0.02	Interest on treasury bills	European Central Bank 2015 Monetary and financial statistics
r_a	0.02	Interest on advances	European Central Bank 2015 Monetary and financial statistics
ξ^{YK}	1	Output to capital stock ratio	Baseline ratios normalized to 1
ξ^{KE}	1	Capital stock to energy ratio	
ξ^{YN}	1	Output to labor ratio	
ξ^{YG}	1	Output to GHG ratio	

Note: Parameters reflect rounded averages of the last 5 years from specified data sources.

Variable	Description
B	Treasury bills
LR, LR^N	Liquidity Ratio (realized, notional)
c, C	Consumption (real, nominal)
D	Deposits
DR	Debt requirement
ED, EB	Energy demand, energy bill
g	Nominal government expenditure
GHG	Greenhouse Gasses
i, I	Capital investment (real, nominal)
in, IN	Inventories (real, nominal)
Inc	Income
k, K	Capital stock (real, nominal)
L	Loans
M	Money stock
p, p^E	Price, price of energy
Π	Profits
s, S	Sales (real, nominal)
u	Capacity utilization rate
ub, UB	Unemployment benefits (real, nominal)
UC	Unit cost
v, V	Wealth (real, nominal)
WB	Wage bill
X	Non renewable input
y, Y	Total firm output (real, nominal)
yd, YD	Disposable income (real, nominal)

D Financial sector

D.1 Commercial Banks

Commercial banks in the model are kept relatively simple. Holding deposits for households against which loans are given out to the production sector.

$$L_t^b = L_t^f + L_t^X + L_t^R \tag{D.1}$$
$$D_t^b = D_t^k + D_t^h \tag{D.2}$$

All loans as assumed to be provided on demand such that the total loans supplied equals L_t^b (D.1) against total household deposits D_t^b (D.2). If the demand for loans exceeds the deposits comercial banks hold, the remaining balance is borrowed from the central bank as advances at an interest rate of r_a. The value of advances equals:

$$A_t^b = \text{Max}[L_t^b - D_t^b, 0] \tag{D.3}$$

The Max condition implies that commercial banks only borrow if liabilities exceed deposits.

Bank profits are derived as

$$\Pi_t^b = r_l L_{t-1}^b - r_d D_{t-1}^b - r_a A_{t-1}^b \tag{D.4}$$

which equal interest received on loans less interest paid on deposits and advances (D.4). As part of the borrowing and lending interest rate norms, the interest rate on loans are kept higher than the interest rate on deposits such that $r_l \geq r_d$. Profits are distributed to capitalist households.

D.2 Central Bank

In the model, the central bank is assumed that acts as the financial arm of the government rather than an independent regulator authority. The central bank issues advances to commercial banks on demand such that

$$A_t^{CB} = A_t^b \tag{D.5}$$

The central bank is also assumed to purchase any Treasury Bills issued by the government:

$$TB_t^{CB} = TB_t \tag{D.6}$$

Profits earned by the central bank equal:

$$\Pi_t^{CB} = r_b TB_{t-1}^{CB} + r_a A_{t-1}^{CB} \tag{D.7}$$

Which are fully redistributed to the government.

Project Information

Welfare, Wealth and Work for Europe

A European research consortium is working on the analytical foundations for a socio-ecological transition

Abstract

Europe needs change. The financial crisis has exposed long-neglected deficiencies in the present growth path, most visibly in the areas of unemployment and public debt. At the same time, Europe has to cope with new challenges, ranging from globalisation and demographic shifts to new technologies and ecological challenges. Under the title of Welfare, Wealth and Work for Europe – WWWforEurope – a European research consortium is laying the analytical foundation for a new development strategy that will enable a socio-ecological transition to high levels of employment, social inclusion, gender equity and environmental sustainability. The four-year research project within the 7th Framework Programme funded by the European Commission was launched in April 2012. The consortium brings together researchers from 34 scientific institutions in 12 European countries and is coordinated by the Austrian Institute of Economic Research (WIFO). The project coordinator is Karl Aiginger, director of WIFO.

For details on WWWforEurope see: www.foreurope.eu

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Goethe University Frankfurt	GUF	Germany
ICLEI - Local Governments for Sustainability	ICLEI	Germany
Institute of Economic Research Slovak Academy of Sciences	IER SAVBA	Slovakia
Kiel Institute for the World Economy	IfW	Germany
Institute of World Economics, RCERS, HAS	KRTK MTA	Hungary
KU Leuven	KUL	Belgium
Mendel University in Brno	MUAF	Czech Republic
Austrian Institute for Regional Studies and Spatial Planning	OIRG	Austria
Policy Network	policy network	United Kingdom
Ratio	Ratio	Sweden
University of Surrey	SURREY	United Kingdom
Vienna University of Technology	TU WIEN	Austria
Universitat Autònoma de Barcelona	UAB	Spain
Humboldt-Universität zu Berlin	UBER	Germany
University of Economics in Bratislava	UEB	Slovakia
Hasselt University	UHASSELT	Belgium
Alpen-Adria-Universität Klagenfurt	UNI-KLU	Austria
University of Dundee	UNIVDUN	United Kingdom
Università Politecnica delle Marche	UNIVPM	Italy
University of Birmingham	UOB	United Kingdom
University of Pannonia	UP	Hungary
Utrecht University	UU	Netherlands
Vienna University of Economics and Business	WU	Austria
Centre for European Economic Research	ZEW	Germany
Coventry University	COVUNI	United Kingdom
Ivory Tower	IVO	Sweden
Aston University	ASTON	United Kingdom