IGEM: A Dynamic General Equilibrium Model for Italy*

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Abstract

This paper provides a description of the Italian General Equilibrium Model (IGEM), a new dynamic general equilibrium model for the Italian economy developed at the Department of Treasury of the Italian Ministry of the Economy and Finance. IGEM integrates typical New Keynesian elements, such as imperfect competition and nominal rigidities, into a general equilibrium framework. One of the key features of the model is the detailed representation of the labor market, designed to capture the dualism of the Italian economic system. The new model will serve as a laboratory for quantitative policy analysis.

Keywords: Dynamic General Equilibrium Model, Quantitative Policy Analysis, Simulation Analysis, Italy.

JEL classification codes: E27, E30, E60.

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1 Introduction

In this paper we present IGEM, a new dynamic general equilibrium (DGE) model for the Italian economy, developed at the Department of Treasury of the Italian Ministry of the Economy and Finance. The model, which is based on explicit microeconomic foundations, has been designed to study the impact and the propagation mechanism of temporary shocks, evaluate the impact of alternative reform scenarios and analyze the effects of single policy interventions and fiscal consolidation packages in Italy.

In recent years, there has been considerable interest in developing DGE models that are better designed to mimic empirical dynamics, study the potential macroeconomic effects of structural reforms and capture the dynamic linkages between the main macroeconomic variables. This modeling approach represents a useful tool for macroeconomic evaluation and policy analysis in an environment which integrates several nominal and real frictions into a fully microfounded setup.

After the seminal papers by Smets and Wouters (2003, 2007) and Christiano et al. (2005), which have shown how the DGE modeling approach can be used as a tool for policy analysis, a number of central banks, ministries and international institutions have developed their own DGE model or have planned to do so in the nearest future.[1]

The model we present in this paper shares several features with the models developed in other institutions. Consistently with conventional New Keynesian (NK) models, IGEM presents a large variety of nominal and real frictions affecting the short- and the medium-term behavior of the economy, while neoclassical features prevail in the long term, where output is determined by technology, preferences and the supply of factor inputs (capital and labor).

IGEM has been designed to capture some specific features of the Italian economy in a general equilibrium setting, so providing a strong framework of analysis able to identify interrelationships and linkages across macroeconomic variables. Contrary to the existing models, in fact, IGEM features a detailed labor market in which different contract types coexist,[2] so to better describe the Italian economy, whose labor market is strongly heterogeneous, and provide a rationale for the existence of low-income households with no access to financial markets. Notably, the dualism of the Italian labor market consists in its separation into a primary sector and a secondary sector. The former is characterized by union coverage, strong job security protection, high firing costs, while the latter is dominated by little or no union coverage, weak security protection and low firing costs. In our model, households with no access to financial markets

[1]Some examples include the International Monetary Fund's Global Economy Model - GEM (see Bayoumi 2004), the New Area Wide Model - NAWM - of the European Central Bank (see Christoffel et al. 2008), SIGMA of the Federal Reserve (see Erceg et al. 2006), the Euro Area and Global Economy - EAGLE - model (see Gomes et al. 2012), the variants of the QUEST model of the European Commission (e.g. Roeger et al. 2008, 2009, Ratto et al. 2009), the Norvegian Economic Model - NEMO - of the Bank of Norway (see Brubakk et al. 2006), the Bank of Canada's Terms-of-Trade Economic Model - ToTEM (see Murchison and Rennison 2006) and the Bank of England Quarterly Model - BEQM (see Harrison et al. 2005).

[2]On the structure of the Italian labor market, see Boeri and Garibaldi (2007), Duranti (2009), Ichino et al. (2005), Lucidi and Kleinknecht (2010). For an example of DGE model embedding dual labor markets, see Mattesini and Rossi (2009).

are mainly identified with workers belonging to this secondary labor market, while the other households supply labor inputs into the primary market. Self-employed workers, instead, are modeled as an additional category which is somehow transversal to both markets. The main parameters governing the supply of labor inputs have been estimated using a microsimulation model named EconLav, in which the behavioral responses of workers are explicitly modeled making use of the information gathered from different statistical sources.[3] Clearly, when exploring the dynamic properties of the model, this heterogeneity in the labor market, coupled with a high degree of real and nominal rigidities, will reveal to be essential in explaining the transmission mechanisms and the effects on employment and income of the business cycle and of different policy interventions.

At this stage of the project the aim was to develop a general framework to be used and extended in the future by adopting a modular approach. Given the complexity and the size of the model, in the present version, except for the labor supply parameters, all other critical ratios and fundamental parameters are calibrated.

The remainder of the paper is as follows. Section 2 provides a non-technical overview of IGEM and discusses the general structure and some key model properties. In Section 3 we present a detailed and technical description of the structure of the model. Section 4 describes the parametrization and the solution strategy. Section 5 considers several applications and presents some simulation scenarios of structural reforms designed to illustrate some specific features of IGEM. Section six concludes.

2 An Overview of IGEM

The skeleton of the model consists of an open economy taking as given the world interest rate, world prices and world demand with six types of economic agents: firms, households, unions, a foreign sector and monetary and fiscal authorities adopting rule-based stabilization policies. Several adjustment costs on nominal and real variables enable IGEM to capture the typical persistence of macroeconomic variables and mimic their empirical dynamics in response to shocks. Specifically, the model features two nominal frictions, convex costs on price and wage adjustment *à la* Rotemberg (1982), and five sources of real rigidities, investment and labor adjustment costs, variable capital utilization, external habit in consumption, and imperfect competition in product and labor markets. All these frictions are necessary to create plausible short-run dynamics, consistently with what it is observed in the data.

The economy presents four types of firms: (i) a continuum of monopolistically competitive firms each of which producing a single tradable differentiated intermediate goods by using labor and physical capital as factor inputs; (ii) a continuum of monopolistically competitive exporting firms transforming domestic intermediate goods into exportable goods using a linear technology;

[3] EconLav is one of the microsimulation tools available at the Department of Treasury of the Italian Ministry of the Economy and Finance. Starting from a detailed description of the fiscal rules and benefit schemes, EconLav is able to represent the behavioral responses of agents to several policy changes. For details see http://www.dt.tesoro.it/en/analisi_programmazione_economico_finanziaria/modellistica/

(iii) a continuum of monopolistically competitive importing firms transforming foreign intermediate goods into importable goods using a linear technology; (iv) perfectly competitive firms combining domestically produced intermediate goods with imported intermediate goods into a final non-tradable good. Domestic producers of intermediate tradeable goods face competition from importers and have to price their products in the domestic market, so as to achieve maximum profits. Similarly, exporters and importers seek to maximize profits by setting prices.

As already emphasized, one of the key features of IGEM consists in a detailed representation of the labor market, designed to capture the main dualism of the Italian labor market characterized by a primary sector with higher protection, better working conditions, superior opportunities for promotion, higher pays, and a secondary sector with poor protection, limited promotion opportunities, lower pays. The labor force of the model, in fact, is divided in three different categories: (i) employees (skilled and unskilled) with a stable contract of employment and strong protection; (ii) atypical workers who have flexible working patterns and weak employment protection; (iii) self-employed workers and professionals who may supply work under contracts for services. Hiring and firing those who are qualified as employees entail high adjustment costs.[4] Similarly, the degree of nominal wage stickiness is much higher for employees, as well as their market power. By contrast, atypical workers who often fail to qualify for employment protection rights, have low hiring and firing costs and no market power. Together with self-employed workers, they represent the more volatile component of the workforce, more subject to the effects of the business cycle fluctuations. In our model, this heterogeneity in the labor market allows us to include a large set of fiscal instruments into the model, opening up to the possibility of exploring the effects of several fiscal and structural reforms aimed at increasing employment, favoring social inclusion and reducing inequalities.

Households consume the final non-tradeable goods supplied by perfectly competitive firms, supply labor and rent out capital to firms. As in Galí et al. (2007) and Forni et al. (2009) IGEM incorporates two types of households: the Ricardian households who have access to financial markets, accumulate physical capital and financial assets and are so able to smooth out their consumption profile in response to shocks (i.e. they manage to keep their lifetime consumption as smooth as possible) and the non Ricardian households who cannot trade in financial markets and accumulate capital, so that as in Campbell and Mankiw (1989), they simply consume their after-tax disposable income (the so called "hand to mouth" consumers). In our model this heterogeneity of households is strictly related to that considered in the labor market. In fact, it is assumed that Ricardian households supply labor services as employees and as self-employed workers, while non Ricardian consumers supply labor services as atypical workers and as unskilled employees.[5] Intuitively, workers with stable contracts have an easy

[4] It should be noted that IGEM does not break down the economy into a shadow and an official economy. As a matter of fact, the dualism of the labor market characterizes the official Italian economy itself.

[5] More precisely, in this model, the category of workers labeled as "atypical" also includes a small fraction of self-employed workers (the young) who may be little different, as no less dependent economically on their work for subsistence than strictly speaking atypical workers. This is also meant to capture the phenomenon of the false independent work.

access to credit, while atypical workers with flexible labor patterns are more likely to be liquidity constrained. Similarly, some low income workers are likely to be liquidity constrained.

Monopolistic trade unions set wages of skilled and unskilled subordinate workers, so as to maximize households' expected utility. Market power introduces a wedge between the real wage rate and the marginal rate of substitution between leisure and consumption. Further, self-employed and professionals are assumed to work on their own under the tutelage of the professional orders (or registers). Hence, despite this category of workers are not covered by the legal and trade-union protections afforded to employees and are paid by their clients or customers, they have some market power in setting their remuneration.

The monetary authority controls the nominal interest rate and responds to inflation and output variations. The model allows for a variety of different reaction functions to be incorporated (active v. passive interest rate rules, current, backward or forward rules).

The government issues nominal debt in the form of interest-bearing bonds. Public consumption and investments, interest payments on outstanding public debt, transfers to households and subsidies to firms are financed by taxes on capital, labor and consumption and/or by issuance of new bonds. To ensure that the fiscal budget constraint is met, the fiscal authority is assumed to adopt a fiscal rule responding to public debt.

The foreign sector is modeled as exogenous. In details, Italy faces an exogenous world rate and takes as given world demand and world prices on tradeable goods. The development of the net foreign asset position depends on the current account surplus and so on the decisions of firms, households and government. The transmission mechanism from internal to external variables is further complicated by the assumption that Italian exporting and importing firms have some market power in the prices they set, so that the net external position will depend on conditions in both financial and goods markets.

3 The Model

The economy is populated by households, unions, final and intermediate goods producing firms, a foreign sector and a monetary and a fiscal authority. The structure of the model consists in a standard neoclassical model, augmented to include a large assortment of real and nominal frictions in the spirit of the so called "New Neoclassical Synthesis". In what follows we outline in detail the behavior of the different types of agents and characterize the competitive equilibrium and the aggregate resource constraint of economy.

3.1 Population Structure and Households

There is a continuum of households in the space $[0,1]$. There are two types of households differing with respect to their ability to access financial markets: the non Ricardian households in the interval $[0,s_{NR}]$, who simply consume their disposable income (i.e. the hand to mouth consumers) and supply differentiated labor services as atypical workers and unskilled employees, and the Ricardian households in the interval $[1 - s_{NR}, 1]$, who are able to smooth consumption over time and supply differentiated labor services as skilled and unskilled employees and as self-employed. The typical household is endowed with one unit of time in each period and divides it between leisure and working efforts. For the sake of simplicity it is assumed that each type of household provides all differentiated labor inputs within each category it supplies. It follows that by denoting s_{N_A}, s_{N_S}, s_{L_L} and s_{L_H}, respectively, the population shares of atypical workers, self-employed workers, unskilled and skilled employees, we have that the following identities must hold:

$$s_{NR} = s_{N_A} + \lambda_{L_L} s_{L_L}, \tag{1}$$

$$1 - s_{NR} = s_{N_S} + s_{L_H} + (1 - \lambda_{L_L}) s_{L_L}, \tag{2}$$

where λ_{L_L} is the share of unskilled labor inputs supplied by non Ricardian households.

3.1.1 Ricardian Households

The representative Ricardian household derives utility from consumption C^R of the final good (where the superscript R stands for "Ricardian") and experiences disutility from supplying labor inputs as unskilled employees L_L, skilled employees L_H and self-employed N_S:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[U(C_t^R - h_{C^R} \overline{C}_{t-1}^R) + \sum_{\ell^R} V_{\ell^R}(1 - \ell_t^R) \right], \tag{3}$$

where E_0 is the expectations operator conditional on information available at time 0, and $\beta \in (0, 1)$ represents the subjective discount factor and $\ell^R \in \{L_L, L_H, N_S\}$ the index denoting the three different categories of workers. Preferences described by the period utility function U displays external habit formation (i.e. "catching up with the Joneses" preferences. See Abel 1990), with $h_{C^R} \in [0, 1)$ being the habit coefficient and $\overline{C}_{t-1}^R$ the lagged aggregate consumption of Ricardian households (taken as given by each household). The typical household derives utility from leisure according to the period utility functions V_{ℓ^R}.

In what follows we adopt the following standard functional forms:

$$u(C_t^R - h_{C^R} \overline{C}_{t-1}^R) = \log \left(C_t^R - h_{C^R} \overline{C}_{t-1}^R \right), \tag{4}$$

$$V_{\ell^R}(1 - \ell_t^R) = \frac{\omega_{\ell^R}}{1 - v_{\ell^R}} \tilde{s}_{\ell^R} \left(1 - \ell_t^R \right)^{1 - v_{\ell^R}}, \tag{5}$$

where ω_{ℓ^R} and v_{ℓ^R} denote category-specific preference parameters and $\tilde{s}_{\ell^R}$ denotes the share of time devoted by the typical Ricardian household to the working activity of kind ℓ^R.[6] Being each household endowed with one unit of time we have $\sum_{\ell^R} \tilde{s}_{\ell^R} = 1$.[7]

[6] The functional form specification in (5) implies that the Frisch elasticity of labor supply is decreasing in the level of hours worked.

[7] It should be noted that from the economy's population structure we have: $\tilde{s}_{L_L} = \frac{(1-\lambda^{L_L}) s_{L_L}}{1 - s_{N_R}}$, $\tilde{s}_{L_H} = \frac{s_{L_H}}{1 - s_{N_R}}$

Ricardian households are assumed to own three assets: government bonds, B^R, paying a gross nominal interest rate equal to R, foreign financial assets, B_F^R, paying a gross rate equal to R^* adjusted for a risk premium ρ^F (increasing in the aggregate level of foreign debt), and physical capital K^R which accumulates according to:

$$K_{t+1}^R = (1-\delta_K)K_t^R + I_t^R, \tag{6}$$

where δ_K denotes the depreciation rate of physical capital and I^R investments. Investment decisions are subject to a convex adjustment cost of $\Gamma_I\left(I_t^R\right)K_t^R$ units of the final good, where

$$\Gamma_I\left(I_t^R\right) = \frac{\gamma_I}{2}\left(\frac{I_t^R}{K_t^R} - \delta_K\right)^2, \quad \gamma_I > 0. \tag{7}$$

Owners of physical capital are also assumed to control the rate of utilization at which this factor is utilized, u_t^K. As in Christiano et al. (2005), using the stock of capital at a rate u_t^K entails a cost in terms of the final good equal to $\Gamma_{u^K}\left(u_t^K\right)K_t^R$, where

$$\Gamma_{u^K}\left(u_t^K\right) = \gamma_{u_1^K}\left(u_t^K - 1\right) + \frac{\gamma_{u_2^K}}{2}\left(u_t^K - 1\right)^2, \quad \gamma_{u_1^K}, \gamma_{u_2^K} > 0. \tag{8}$$

Households rent out their capital stock to the intermediate goods producing firms and receive a competitive rental price, r_t^K, per unit of capital. Given the degree of capital utilization u_t^K, total gross income stemming from the rental amounts to $r_t^K u_t^K K_t^R$.

Households earn a gross labor income equal to $\sum_{\ell^R} \tilde{s}_{\ell^R} W_t^{\ell^R} \ell_t^R$ and labor decisions are made by unions which supply labor in monopolistic competitive markets and face Rotemberg-type quadratic adjustment costs in terms of domestic production, Y_t, on nominal wage changes specific for each category of represented workers, $\Gamma_{W^{\ell^R}}(W_t^{\ell^R})Y_t$.

Finally, households receive dividends, PRO^R, from the intermediate goods firms, transfers from the government, Tr^R, and pay lump-sum taxes, TAX^R, consumption taxes (at a rate τ^C), wage income taxes (at rates $\tau_t^{\ell^R}$) and capital income taxes (τ^K), less depreciation allowances and tax credit (tcr^K). Finally, we also assume that households pay contributions to social security (at rates $\tau_{h,t}^{W^{\ell^R}}$).

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and $\tilde{s}_{N_S} = \frac{s_{N_s}}{1-s_{N_R}}$, so that on aggregate the labor force supplied by Ricardian households is exactly $1 - s_{NR} = s_{N_S} + s_{L_H} + (1-\lambda_{L_L})\, s_{L_L}$.

The period-by-period budget constraint for the typical Ricardian agent reads as:

$$(1+\tau_t^C)P_{C,t}C_t^R + B_t^R + S_t B_{F,t}^R + P_{I,t}I_t^R = \left(1-\tau_t^{\ell^R} - \tau_{h,t}^{W^{\ell^R}}\right)\sum_{\ell^R}\tilde{s}_{\ell^R}W_t^{\ell^R}\ell_t^R + \tag{9}$$
$$+R_{t-1}B_{t-1}^R + (R_{t-1}^* + \rho_{t-1}^F)S_t B_{F,t-1}^R +$$
$$+\left(PRO_t^R + Tr_t^R - TAX_t^R\right)P_t$$
$$+\tau_t^K \delta_K P_{I,t} u_t^K K_t^R + tcr_t^K P_{I,t} I_t^R +$$
$$+(1-\tau_t^K) r_t^K P_{I,t} u_t^K K_t^R - P_{I,t}\Gamma_I\left(I_t^R\right)K_t^R +$$
$$-P_{I,t}\Gamma_{u^K}\left(u_t^K\right)K_t^R - P_t\sum_{\ell^R}\tilde{s}_{\ell^R}\Gamma_{W^{\ell^R}}(W_t^{\ell^R})Y_t,$$

where P_C denotes the price of a unit of the consumption good, P_I the price of a unit of the investment good, S_t is the nominal exchange rate defined as units of domestic currency per unit of foreign currency, P_t is the price level. The solution to the Ricardian household problem is summarized in Appendix A.

3.1.2 Non Ricardian Households

The representative non Ricardian household faces a periodic utility function of the form:

$$U(C_t^{NR} - h_{C^{NR}}\overline{C}_{t-1}^{NR}) + \sum_{\ell^{NR}} V_{\ell^{NR}}(1-\ell_t^{NR}), \tag{10}$$

where all variables are as in the previous section and the superscript NR stands for "non Ricardian". As already mentioned, non Ricardian households only supply labor services as atypical workers and as unskilled employees (represented by trade unions), hence $\ell^{NR} \in \{L_L, N_A\}$. We assume that functional forms of $U(\cdot)$ and $V(\cdot)$ are as in (4) and (5). By assumption, non Ricardian households have no access to financial markets and do not own physical capital (i.e. non Ricardian households can neither save nor borrow), hence they derive income only from labor activities, adjusted for taxation. The flow budget constraint in nominal terms reads as:

$$\begin{aligned}(1+\tau_t^C)P_{C,t}C_t^{NR} &= \left(1-\tau_t^{\ell^{NR}} - \tau_{h,t}^{W^{\ell^{NR}}}\right)\sum_{\ell^{NR}}\tilde{s}_{\ell^{NR}}W_t^{\ell^{NR}}\ell_t^{NR} + \\ &\quad -\sum_{\ell^{NR}}\tilde{s}_{\ell^{NR}}\Gamma_{W^{\ell^{NR}}}(W_t^{\ell^{NR}})Y_t + P_t\left(Tr^{NR} - TAX_t^{NR}\right),\end{aligned} \tag{11}$$

where Tr^{NR} and TAX^{NR} denote government transfers and lump-sum taxes and $\Gamma_{W^{\ell^{NR}}}(W_t^{\ell^{NR}})$ denotes the nominal wage adjustment costs faced by non-Ricardian individuals in changing nominal wages. We assume that atypical workers are not represented by trade unions, so that individuals supply atypical labor services taking wage as given. See Appendix A for details.

3.2 Wage Setting and Labor Supply

For self-employed workers and skilled and unskilled employees labor decisions are made by a central authority within the household: a professional order will act in the interest of each variety of labor services supplied as self-employed and a union will represent each variety of labor services supplied as employee. Atypical workers, instead, have no market power and supply labor services taking wage as given. See Appendix A for details.

3.2.1 Self-Employed Workers

For the self-employed labor decisions are taken under the tutelage of professional orders which supply labor services monopolistically to a continuum of labor markets of measure 1 indexed by $h_{N_S} \in [0,1]$. It is assumed that in each market h_{N_S} the professional order faces a demand for labor given by $N_{S,t}(h_{N_{S,t}}) = \left(\frac{W_t^{N_S}(h_{N_S})}{W_t^{N_S}}\right)^{-\sigma_{N_S}} N_{S,t}$, where $\sigma_{N_S} > 1$ is the elasticity of substitution between labor inputs, $W_t^{N_S}(h_{N_S})$ is the market-specific nominal retribution, $W_t^{N_S}$ is the wage index and $N_{S,t} = \int_0^1 N_{S,t}(h_{N_S}) dh_{N_S}$ so to satisfy the time resource constraint.

The monopolistic professional order sets $W_t^{N_S}(h_{N_{S,t}})$ in order to maximize households' expected utility (3), given the demand for its differentiated labor services and subject to a convex adjustment costs function:

$$\Gamma_{W^{N_S}}(W_t^{N_S}(h_{N_S})) = \frac{\gamma_{W^{N_S}}}{2}\left(\frac{1}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{W_t^{N_S}(h_{N_s})}{W_{t-1}^{N_S}(h_{N_s})} - 1\right)^2 Y_t, \tag{12}$$

where $\gamma_{W^{N_S}} > 0$ and $\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W}$ is a geometric average of past (gross) and long-run inflation, where the weight of past inflation is determined by the indexation parameter $\kappa_W \in [0,1]$.

The first-order condition for labor supply, $N_{S,t}$, in the symmetric steady-state equilibrium reads as:

$$\frac{W^{N_S}}{P} = \frac{\sigma_{N_S}}{\sigma_{N_S} - 1}\frac{1}{1 - \tau^{N_S} - \tau_h^{W^{N_S}}}\frac{\omega_{N_S}}{\lambda^R (1 - N_s)^{\upsilon_{N_S}}}, \tag{13}$$

where λ^R is the Lagrange multiplier associated to the budget constraint (9) expressed in real terms. Notice that market power in the labor market introduces a wedge between the real remuneration of self-employed workers, W^{N_S}/P, and the marginal rate of substitution between leisure and consumption adjusted for direct and indirect taxation. This markup $\frac{\sigma_{N_S}}{\sigma_{N_S}-1}$ is decreasing in the elasticity of substitution between differentiated labor services, σ_{N_S}, and reflects the degree of imperfect competition characterizing the labor market. The impact of structural reforms aimed at increasing the degree of competition among self-employed, such as the liberalization of professional orders, can be simulated by permanently modifying the elasticity parameter σ_{N_S}.

3.2.2 Skilled Employees

Within each Ricardian household, a union is assumed to supply labor inputs as skilled employee monopolistically to a continuum of labor markets of measure 1 indexed by $h_{L_H} \in [0,1]$. In each market, the union faces a demand for labor given by $L_{H,t}(h_{L_H}) = \left(\frac{W_t^{L_H}(h_{L_H})}{W_t^{L_H}}\right)^{-\sigma_{L_H}} L_{H,t}$ where $\sigma_{L_H} > 1$ is the elasticity of substitution between differentiated labor services, $W_t^{L_H}(h_{L_H})$ is the market-specific nominal wage, $W_t^{L_H}$ is the wage index and $L_{H,t} = \int_0^1 L_{H,t}(h_{L_H}) dh_{L_H}$. We also assume for employees costly nominal wages adjustment of the form $\Gamma_{W^{L_H}}(W_t^{L_H}(h_{L_H})) = \frac{\gamma_{W^{L_H}}}{2} \left(\frac{1}{\Pi_{t-1}^{\kappa_W} \overline{\Pi}^{1-\kappa_W}} \frac{W_t^{L_H}(h_{L_H})}{W_{t-1}^{L_H}(h_{L_H})} - 1\right)^2 Y_t$, where $\gamma_{W^{L_H}} > 0$.

In steady-state and imposing symmetry across differentiated skilled labor services, the wage equation boils down to

$$\frac{W^{L_H}}{P} = \frac{\sigma_{L_H}}{\sigma_{L_H} - 1} \frac{1}{1 - \tau^{L_H} - \tau_h^{W^{L_H}}} \frac{\omega_{L_H}}{\lambda^R (1 - L_H)^{v_{L_H}}}. \tag{14}$$

It follows that reforms, aimed at reducing the bargaining power of insiders and align wages to productivity trends, are simply mapped onto the model by increasing the elasticity of substitution between pairs of differentiated skilled labor inputs so to reduce the wage markup $\frac{\sigma_{L_H}}{\sigma_{L_H}-1}$.

3.2.3 Unskilled Employees

Unskilled labor services are assumed to be supplied by both Ricardian and non Ricardian households. As for skilled employees, we assume a continuum of differentiated labor inputs indexed by $h_{L_L} \in [0,1]$ supplied monopolistically by unions. For simplicity we assume that households are distributed uniformly across unions, hence aggregate demand of labor type h_{L_L}, that is $L_{L,t}(h_{L_L}) = \left(\frac{W_t^{L_L}(h_{L_L})}{W_t^{L_L}}\right)^{-\sigma_{L_L}} L_{L,t}$, is evenly distributed between all households, with $\sigma_{L_L} > 1$ denoting the elasticity of substitution between differentiated labor services, $W_t^{L_L}(h_{L_L})$ is the nominal wage of type h_{L_L}, $W_t^{L_L}$ is the wage index of the category and $L_{L,t} = \int_0^1 L_{L,t}(h_{L_L}) dh_{L_L}$. It follows that a share λ^{L_L} of the associates are non Ricardian consumers, while the remaining share is composed by Ricardian agents. The union will set the nominal wage $W_t^{L_L}(h_{L_L})$, so as to maximize a weighted average of agents' lifetime utilities. Adjustment costs on nominal wages are given by a quadratic cost function, $\Gamma_{W^{L_L}}(W_t^{L_L}(h_{L_L})) = \frac{\gamma_{W^{L_L}}}{2} \left(\frac{1}{\Pi_{t-1}^{\kappa_W} \overline{\Pi}^{1-\kappa_W}} \frac{W_t^{L_L}(h_{L_L})}{W_{t-1}^{L_L}(h_{L_L})} - 1\right)^2$ Y_t, where $\gamma_{W^{L_L}} > 0$.

In steady state the first-order condition for wage setting, after having imposed symmetry across differentiated unskilled labor services, reads as follows:

$$\frac{W^{L_L}}{P} = \frac{\sigma_{L_L}}{\sigma_{L_L}-1}\frac{1}{1-\tau^{L_L}-\tau_h^{W^{L_L}}}\frac{\omega_{L_L}}{\left[(1-\lambda^{L_L})\lambda^R+\lambda^{L_L}\lambda^{NR}\right](1-L_L)^{v_{LL}}}, \tag{15}$$

where we have used the fact that given the population structure the weights attached by the union to Ricardian and non Ricardian households are given by $(1 - s_{NR})$ and s_{NR}, respectively, and that given the allocation of time within each household, the effective weights boil down to $(1-\lambda_{L_L})$ and λ_{L_L}, respectively.[8] By permanently modifying the elasticity parameter σ_{L_L} we are able to alter the market power of the trade unions representing unskilled labor workers.

3.2.4 Atypical Workers

By assumption, only non Ricardian households supply labor services as atypical workers. For this category of workers, with no union coverage, the labor supply equation solves the optimization problem of the typical non Ricardian household and equates the real wage to marginal rate of substitution between leisure and consumption:

$$\frac{W_t^{N_A}}{P_t} = \frac{1}{1-\tau_t^{N_A}-\tau_{h,t}^{W^{N_A}}}\frac{\omega_{N_A}}{\lambda_t^{NR}(1-N_{A,t})^{v_{N_A}}}. \tag{16}$$

According to the above condition, it is possible to increase labor supply of atypical workers simply by reducing the tax wedge.

3.3 Firms

The economy features four types of firms: (i) a continuum of firms producing differentiated tradable intermediate goods; (ii) a continuum of monopolistically competitive exporting firms transforming domestic tradeables into exportable goods using a linear technology; (iii) a continuum of monopolistically competitive importing firms transforming foreign tradeables into importable goods using a linear technology; (iv) perfectly competitive firms producing a final non-tradable good by combining domestically produced intermediate goods with imported intermediate goods. In Appendix A we report the first-order conditions characterizing the optimal solution to the firms problem.

3.3.1 Intermediate-Good Firms

The intermediate goods sector is made by a continuum of monopolistically competitive producers indexed by $j \in [0, 1]$. The typical firm j uses labor inputs and capital to produce intermediate

[8] Given the population structure and the allocation of time within each household, the weights attached by the union to Ricardian and non Ricardian households are, in fact, given by $(1-s_{NR})\frac{1-\lambda_{L_L}}{1-s_{NR}}s_{L_L}$ and $s_{NR}\frac{\lambda_{L_L}}{s_{NR}}s_{L_L}$.

goods $Y_t(j)$ according to the following technology:

$$Y_t(j) = A_t \left[\left(L_{CES,t}(j) - OH_t^L\right)^{\alpha_L} \left(N_{CES,t}(j) - OH_t^N\right)^{\alpha_N} \left(u_t^K K_t(j)\right)^{1-\alpha_L-\alpha_N} \right]^{1-\alpha_G} KG_t^{\alpha_G}, \tag{17}$$

where $0 < \alpha_L, \alpha_N, \alpha_G < 1$, $\alpha_L + \alpha_N < 1$, A_t denotes total factor productivity, $L_{CES,t}$ and $N_{CES,t}$ denote CES aggregates of labor inputs hired as employees and as self-employed and atypical workers. The first bundle represents a combination of skilled and unskilled labor inputs hired in less competitive markets with more stable labor contracts, while the second bundle includes labor inputs hired in the form of more flexible labor patterns. OH_t^L and OH_t^N stand for overhead labor which captures the notion that a firm must employ a minimum amount of labor to produce any output (this includes tasks like management, supervision, breaks, meetings, maintenance, time spent with government bureaucracy), while KG_t is the stock of government capital whose level depends on the public infrastructure investment decisions I_t^G and evolves as $KG_t = (1-\delta_G)KG_{t-1} + I_t^G$, with δ_G being the depreciation rate. This productive role of government capital in the spirit of Barro (1990), creates a potentially positive linkage between government and output. Note that production exhibits decreasing returns to private inputs if the (complementary) government capital inputs do not expand in a parallel manner.

The labor aggregates $L_{CES,t}$ and $N_{CES,t}$ are defined as follows:

$$L_{CES,t} = \left[sy_{L_L}^{\frac{1}{\sigma_L}} \left(ef_{L_L} LY_{L,t}\right)^{\frac{\sigma_L - 1}{\sigma_L}} + sy_{L_H}^{\frac{1}{\sigma_L}} \left(ef_{L_H} LY_{H,t}\right)^{\frac{\sigma_L - 1}{\sigma_L}} \right]^{\frac{\sigma_L}{\sigma_L - 1}}, \tag{18}$$

$$N_{CES,t} = \left[sy_{N_S}^{\frac{1}{\sigma_N}} \left(ef_{N_S} NY_{S,t}\right)^{\frac{\sigma_N - 1}{\sigma_N}} + sy_{N_A}^{\frac{1}{\sigma_N}} \left(ef_{N_A} NY_{A,t}\right)^{\frac{\sigma_N - 1}{\sigma_N}} \right]^{\frac{\sigma_N}{\sigma_N - 1}}, \tag{19}$$

where we have dropped index j to save on notation, $\sigma_L, \sigma_N > 1$ measure the elasticity of substitution between the categories of workers of each CES aggregate, the coefficients ef_{L_L}, ef_{L_H}, ef_{N_S}, ef_{N_A} measure efficiency, the terms sy_{L_L}, sy_{L_H}, sy_{N_S}, sy_{N_A} represent the shares of each category of workers in their respective aggregate and $LY_{L,t}$, $LY_{H,t}$, $NY_{S,t}$, $NY_{A,t}$ denote the labor inputs. Labor inputs $LY_{L,t}$, $LY_{H,t}$, $NY_{S,t}$, are, in turn, CES bundles of differentiated labor inputs with elasticity of substitution equal to σ_{L_L}, σ_{L_H} and σ_{N_S}, respectively, so that at the optimum and after aggregation across the continuum of intermediated-good firms j, the demand schedule for each variety within each category will be as outlined in the previous section on wage setting.

The production function (17) with (18) and (19) has a particular nesting structure which deserves some more explanation. The idea here is to capture the fact that a production unit needs to employ labor services both in stable and in more flexible patterns.[9] As a matter of fact, on the one hand, firms need more stabilized workers (on whom they can always count) involved in the core business activities and in those which are strictly functional to these activities

[9] Other nesting hypotheses will be considered in future extensions, since the quantitative effects of policy interventions on hours worked and labor remuneration of the single categories of workers can considerably change.

themselves, on the other, firms externalize activities that do not involve core competencies, relying on workers who supply their services as self-employed or atypical workers. Furthermore, the possibility of having substitutability between self-employed and atypical is meant to capture some particular features of the Italian labor markets. In the first place, atypical workers in Italy are not necessarily low skilled and in most cases they have tertiary education.[10] Secondly, as already explained, the category of workers labeled as atypical, also includes a small fraction of self-employed workers (the young), so to capture the phenomenon of the false independent work. In addition, firms tend to employ a core of permanent workers on whom an investment in training is made to increase productivity and obtain better functional flexibility. Yet, firms are also likely to employ a group of peripheral workers or rely on external services to be able to better meet temporary changes in the economic conditions.

Firms are assumed to pay social contributions at rates $\tau_f^{W^{L_H}}$, $\tau_f^{W^{L_L}}$, $\tau_f^{N_A}$ and $\tau_f^{W^{N_S}}$, respectively for skilled and unskilled employees, atypical workers and self-employed workers, and may receive incentives in the form of subsidies for hiring workers with the (exception of self-employed) at the differentiated rates sub^{L_H}, sub^{L_L}, sub^{N_A}.

The objective of each firm j is to maximize the sum of expected discounted real profits by setting the optimal price $P_t(j)$ and making choices about labor inputs and physical capital, given the available technology (17), the demand schedule for variety j, $Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\theta_Y} Y_t$,[11] quadratic adjustment costs on price setting:

$$\Gamma_P(P_t(j)) = \frac{\gamma_P}{2}\left(\frac{1}{\Pi_{t-1}^{\kappa_P}\overline{\Pi}^{1-\kappa_P}}\frac{P_t\left(j\right)}{P_{t-1}\left(j\right)} - 1\right)^2 Y_t, \tag{20}$$

with $\gamma_p > 0$ and $\kappa_P \in [0,1]$ denoting weight of past inflation in the indexation, and quadratic adjustment costs on labor inputs changes:

$$\Gamma_{L_H}(LY_H(j)) = \frac{\gamma_{L_H}}{2}\left(\frac{LY_{H,t}\left(j\right)}{LY_{H,t-1}\left(j\right)} - 1\right)^2 Y_t, \tag{21}$$

$$\Gamma_{L_L}(LY_L(j)) = \frac{\gamma_{L_L}}{2}\left(\frac{LY_{L,t}\left(j\right)}{LY_{L,t-1}\left(j\right)} - 1\right)^2 Y_t, \tag{22}$$

$$\Gamma_{N_S}(NY_S(j)) = \frac{\gamma_{N_S}}{2}\left(\frac{NY_{S,t}\left(j\right)}{NY_{S,t-1}\left(j\right)} - 1\right)^2 Y_t, \tag{23}$$

$$\Gamma_{N_A}(NY_A(j)) = \frac{\gamma_{N_A}}{2}\left(\frac{NY_{A,t}\left(j\right)}{NY_{A,t-1}\left(j\right)} - 1\right)^2 Y_t, \tag{24}$$

where we assume that $0 < \gamma_{N_A} < \gamma_{N_S} < \gamma_{L_H} = \gamma_{L_L}$ in order to capture the higher costs associated with changes in the labor inputs related to workers with stable contracts.

[10] See ISFOL (2012). As an example, in 2010 about 30% of workers with tertiary education, since four years from the first job, were still "temporary".

[11] The intermediate good j is demanded by final good firms to produce consumption and investment goods and by exporters to produce tradable goods.

Optimal Price Setting The elasticity of substitution between products of differentiated intermediate goods, θ_Y, determines the market power of each firm. In steady state, the first order condition for price setting reads as:

$$P = \frac{\theta_Y}{\theta_Y - 1} MC^N, \tag{25}$$

where MC^N denotes the nominal marginal cost. The above result implies that in the steady state the real marginal cost, $MC = MC^N/P$, is equal to the inverse of the markup (measuring the degree of market power of intermediate-good producers), that is $MC = \frac{\theta_Y - 1}{\theta_Y}$. Pro-competitive reforms in the production market are simulated by increasing the elasticity of substitution between pairs of intermediate goods varieties θ_Y.

Capital and Labor Inputs Decisions Under symmetry, the first-order condition to the optimization problem with respect to physical capital inputs is given by:

$$\frac{P_t^I}{P_t} u_t^K r_t^k = (1 - \alpha_G)(1 - \alpha_L - \alpha_N) MC_t \frac{Y_t}{K_t}. \tag{26}$$

where u_t^K is the capital utilization rate decided by households and r_t^k is the rental cost.

Turning to the decisions on labor inputs, in steady state, the following first-order conditions must hold for unskilled and skilled employees, atypical and self-employed workers:

$$\frac{W^{L_L}}{P}\left(1 - sub^{L_L} + \tau_f^{W^{L_L}}\right) = \alpha_L (1 - \alpha_G) MC \frac{Y}{L_{CES} - OH^L} \left(\frac{L_{CES}}{LY_L}\right)^{\frac{1}{\sigma_L}} s_{L_L}^{\frac{1}{\sigma_L}} ef_{L_L}^{\frac{\sigma_L - 1}{\sigma_L}}, \tag{27}$$

$$\frac{W^{L_H}}{P}\left(1 - sub^{L_H} + \tau_f^{W^{L_H}}\right) = \alpha_L (1 - \alpha_G) MC_t \frac{Y_t}{L_{CES,t} - OH_t^L} \left(\frac{L_{CES,t}}{LY_H}\right)^{\frac{1}{\sigma_L}} s_{L_H}^{\frac{1}{\sigma_L}} ef_{L_H}^{\frac{\sigma_L - 1}{\sigma_L}}, \tag{28}$$

$$\frac{W^{N_A}}{P}\left(1 - sub^{N_A} + \tau_f^{W^{N_A}}\right) = \alpha_N (1 - \alpha_G) MC \frac{Y_t}{N_{CES} - OH^N} \left(\frac{N_{CES}}{NY_A}\right)^{\frac{1}{\sigma_N}} s_{N_S}^{\frac{1}{\sigma_N}} ef_{N_S}^{\frac{\sigma_N - 1}{\sigma_N}}, \tag{29}$$

$$\frac{W^{N_S}}{P}\left(1 + \tau_f^{W^{N_S}}\right) = \alpha_N (1 - \alpha_G) MC \frac{Y}{N_{CES} - OH^N} \left(\frac{N_{CES}}{NY_S}\right)^{\frac{1}{\sigma_N}} s_{N_S}^{\frac{1}{\sigma_N}} ef_{N_S}^{\frac{\sigma_N - 1}{\sigma_N}}. \tag{30}$$

Clearly, payroll taxes and subsidies introduce a wedge between the wage rate and the marginal revenue of labor inputs.

3.3.2 Exporting and Importing Firms

We assume the existence of a continuum of monopolistically competitive exporting firms transforming domestic intermediate goods into exportable goods using a linear technology. This implies that exporters are able to set the price for their product at a markup over their marginal cost. Furthermore, we assume that there are costs to adjusting prices:

$$\Gamma_{P_X}(P_{X,t}(j)) = \frac{\gamma_{EXP}}{2}\left[\frac{1}{\left(\Pi^*_{t-1}\right)^{\kappa_{EXP}}\left(\overline{\Pi}^*\right)^{1-\kappa_{EXP}}}\frac{P_{X,t}(j)}{P_{X,t-1}(j)} - 1\right]^2 EXP_t, \tag{31}$$

where $P_{X,t}(j)$ is the price set by the exporter in foreign currency for the good j, $\gamma_{EXP} > 0$, $\left(\Pi^*_{t-1}\right)^{\kappa_{EXP}}\left(\overline{\Pi}^*\right)^{1-\kappa_{EXP}}$ is a geometric average of past (gross) and long-run inflation prevailing in the foreign market, where the weight of past inflation is determined by the indexation parameter $\kappa_{EXP} \in [0,1]$.

The typical exporting firm will thus set the exporting price $P_{X,t}(j)$, so as to maximize the expected discounted value of future profits, taking as given the adjustment cost (31), the exchange rate S_t and the world demand for good j $EXP_t(j) = \left(\frac{P_{X,t}(j)}{P_{X,t}}\right)^{-\theta_{EXP}} EXP_t$, where $\theta_{EXP} > 1$ is the elasticity of substitution between tradeable goods, EXP_t denotes the total demand of exportations and $P_{X,t}$ is the ideal export price index, given by $P_{X,t} = \left[\int_0^1 P_{X,t}(j)^{1-\theta_{EXP}} dj\right]^{\frac{1}{1-\theta_{EXP}}}$. In steady state the markup charged by exporting firms will be constant:

$$SP_X = \frac{\theta_{EXP}}{\theta_{EXP} - 1}P. \tag{32}$$

By analogy, the same logic applies to importers, which are domestic firms setting prices in local currency as a markup over the import price of intermediate goods produced abroad and facing a demand $IMP_t(j) = \left(\frac{P_{M,t}(j)}{P_t^M}\right)^{-\theta_{IMP}} IMP_t$ where $\theta_{IMP} > 1$ is the elasticity of substitution between imported goods, IMP_t denotes the total demand of imported goods, $P_{M,t}(j)$ is the price of the imported good expressed in domestic currency and $P_{M,t}$ is the ideal import price index, given by $P_{M,t} = \left[\int_0^1 P_{M,t}(j)^{1-\theta_{IMP}} dj\right]^{\frac{1}{1-\theta_{IMP}}}$. Since we assume an identical setup for importing firms, the quadratic cost function to adjusting prices is:

$$\Gamma_{P_M}(P_{M,t}(j)) = \frac{\gamma_{IMP}}{2}\left[\frac{1}{\Pi_{t-1}^{\kappa_{IMP}}\overline{\Pi}^{1-\kappa_{IMP}}}\frac{P_{M,t}(j)}{P_{M,t-1}(j)} - 1\right]^2 IMP_t, \tag{33}$$

where $\gamma_{IMP} > 0$ and $\kappa_{IMP} \in [0,1]$. Notice that in steady state the optimal pricing condition of the typical importing firm is:

$$P_M = \frac{\theta_{IMP}}{\theta_{IMP-1}}SP^*. \tag{34}$$

3.3.3 Final-Good Firms

We assume that firms producing final non-tradable goods are symmetric and act under perfect competition. Final goods can be used for private and public consumption and for private and public investment.

The representative firm producing the final non-tradable good E_t combines a bundle of domestically produced intermediate goods $Y_{H,t}$ with a bundle of imported intermediate goods

IMP_t according to a constant elasticity of substitution (CES) technology:

$$E_t = \left[(1-\alpha_{IMP})^{\frac{1}{\sigma_{IMP}}} Y_{H,t}^{\frac{\sigma_{IMP}-1}{\sigma_{IMP}}} + \alpha_{IMP}{}^{\frac{1}{\sigma_{IMP}}} IMP_t^{\frac{\sigma_{IMP}-1}{\sigma_{IMP}}} \right]^{\frac{\sigma_{IMP}}{\sigma_{IMP}-1}}, \tag{35}$$

where σ_{IMP} is the elasticity of substitution between domestically produced goods and internationally produced goods, α_{IMP} represents the share of foreign intermediate goods used in the production of the final goods and

$$Y_{H,t} = \left[\int_0^1 Y_{H,t}(j)^{\frac{\theta_Y - 1}{\theta_Y}} dj \right]^{\frac{\theta_Y}{\theta_Y - 1}}, \tag{36}$$

$$IMP_t = \left[\int_0^1 IMP_t(j)^{\frac{\theta_{IMP} - 1}{\theta_{IMP}}} dj \right]^{\frac{\theta_{IMP}}{\theta_{IMP} - 1}}, \tag{37}$$

where θ_Y, $\theta_{IMP} > 1$ denote the elasticities of substitution between the differentiated intermediate goods produced at home and abroad. At the optimum:

$$Y_{H,t} = (1-\alpha_{IMP}) \left(\frac{P_t}{P_{E,t}} \right)^{-\sigma_{IMP}} E_t, \tag{38}$$

$$IMP_t = \alpha_{IMP} \left(\frac{P_{M,t}}{P_{E,t}} \right)^{-\sigma_{IMP}} E_t, \tag{39}$$

where the price index $P_{E,t}$ is defined as:

$$P_{E,t} \equiv \left[(1-\alpha_{IMP}) (P_t)^{1-\sigma_{IMP}} + \alpha_{IMP} (P_{M,t})^{1-\sigma_{IMP}} \right]^{\frac{1}{1-\sigma_{IMP}}}. \tag{40}$$

Furthermore, at the optimum the demand of each domestically produced variety is defined as:

$$Y_{H,t}(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\theta_Y} Y_{H,t}. \tag{41}$$

Perfect competition and free entry drive the final good-producing firms' profits to zero, so that from the zero-profit condition we obtain:

$$P_t = \left[\int_0^1 P_t(j)^{1-\theta_Y} dj \right]^{\frac{1}{1-\theta_Y}}. \tag{42}$$

which defines the aggregate price index of our economy.

Similarly, the demand of each foreign variety is defined as:

$$IMP_t(j) = \left(\frac{P_{M,t}(j)}{P_{M,t}} \right)^{-\theta_{IMP}} IMP_t \tag{43}$$

Perfect competition and free entry drive the final good-producing firms' profits to zero, so that from the zero-profit condition we obtain:

$$P_{M,t} = \left[\int_0^1 P_{M,t}(j)^{1-\theta_{IMP}} dj \right]^{\frac{1}{1-\theta_{IMP}}} . \tag{44}$$

3.4 Fiscal and Monetary Authorities

The government purchases final goods for consumption C_t^G and investment I_t^G, makes transfers to households Tr_t, gives subsidies to intermediate goods producers SUB_t, receives lump-sum taxes TAX_t and tax payments on labor income, consumption and capital $LTAX_t, CTAX_t, KTAX_t$, and issues nominal bonds B_t.

The flow budget constraint of the government in nominal terms is then:

$$\begin{aligned} B_t &= R_{t-1}B_{t-1} + P_{C,t}C_t^G + P_{I,t}I_t^G + P_t Tr_t + \\ &\quad -P_t TAX_t - P_t \left(LTAX_t + CTAX_t + KTAX_t \right) + P_t SUB_t, \end{aligned} \tag{45}$$

where

$$TAX_t = s_{NR}TAX_t^{NR} + (1 - s_{NR})TAX_t^R \tag{46}$$

$$Tr_t = s_{NR}Tr_t^{NR} + (1 - s_{NR})Tr_t^R, \tag{47}$$

$$\begin{aligned} LTAX_t &= s_{L_L} L_{L_L} WR^{L_L} \left(\tau_t^{L_L} + \tau_{h,t}^{W_{L_L}} + \tau_{f,t}^{W_{L_L}} \right) + \\ &\quad + s_{L_H} L_{L_H} WR^{L_H} \left(\tau_t^{L_H} + \tau_{h,t}^{W_{L_H}} + \tau_{f,t}^{W_H} \right) + \\ &\quad + s_{N_S} L_{N_S} WR^{N_S} \left(\tau_t^{N_S} + \tau_{h,t}^{W_{N_s}} + \tau_{f,t}^{W^{N_S}} \right) + \\ &\quad + s_{N_A} L_{N_A} WR^{N_A} \left(\tau_t^{N_A} + \tau_{h,t}^{W_{N_A}} + \tau_{f,t}^{W_{N_A}} \right), \end{aligned} \tag{48}$$

$$CTAX_t = \tau_t^C \left[s_{NR}C_t^{NR} + (1 - s_{NR})C_t^R \right], \tag{49}$$

$$KTAX_t = \tau_t^K \left(r_t^K - \delta^K \right) u_t^K K_t - tcrk_t \frac{P_{I,t}}{P_t} I_t, \tag{50}$$

$$SUB_t = sub_t^{L_L} s_{L_L} L_L WR^{L_L} + sub_t^{L_H} s_{L_H} L_H WR^{L_H} + sub_t^N S_{N_A} N_A WR^{N_A}, \tag{51}$$

with $WR^{L_L} = W^{L_L}/P$, $WR^{L_H} = W^{L_H}/P$, $WR^{N_A} = W^{N_A}/P$ and $WR^{N_S} = W^{N_S}/P$.

The lump-sum component of taxation is set endogenously according to the following "passive rule" as meant by Leeper (1991):

$$P_t TAX_t = P_t \overline{TAX} + T_B \left(B_{t-1} - \overline{B} \right) + T_D D_t + T_Y P_t \left(Y_t - Y_{t-1} \right). \tag{52}$$

where T_B, T_D and T_Y are policy parameters, $\overline{TAX}$ and $\overline{B}$ are the long-run level of lump-sump taxation and of public debt, and D_t denotes the budget deficit:

$$\begin{aligned} D_t &= (R_{t-1}-1)B_{t-1} + P_{C,t}C_t^G + P_{IG,t}I_t^G + P_t Tr_t + \\ &\quad -P_t TAX_t - P_t\left(LTAX_t + CTAX_t + KTAX_t\right) + P_t SUB_t. \end{aligned} \tag{53}$$

The monetary authority adopts a Taylor-type interest rate rule specified as follows:

$$\frac{R_t}{\overline{R}} = \left(\frac{R_{t-1}}{\overline{R}}\right)^{\iota_R}\left[\left(\frac{\Pi_t}{\Pi^T}\right)^{\iota_\Pi}\left(\frac{Y_t}{Y_{t-1}}\right)^{\iota_Y}\left(\frac{S_t}{S_{t-1}}\right)^{\iota_S}\right]^{1-\iota_R}\varepsilon_t^R. \tag{54}$$

where $\overline{R}$ is the equilibrium nominal interest rate, Π^T is the monetary authority inflation target, ε_t^R is an exogenous process describing possible monetary policy shocks and ι_R, ι_Π, ι_Y, ι_S are policy parameters.

3.5 Aggregation and Foreign Asset Position

Since only Ricardian households hold financial assets, accumulate physical capital and own domestic firms, equilibrium requires that the following conditions must be satisfied: $(1-s_{NR})B_t^R = B_t$, $(1-s_{NR})B_{F,t}^R = B_{F,t}$, $(1-s_{NR})I_t^R = I_t$, $(1-s_{NR})K_t^R = K_t$, $(1-s_{NR})PRO_t^R = PRO_t$ while aggregate consumption is:

$$C_t = (1-s_{NR})C_t^R + s_{NR}C_t^{NR}. \tag{55}$$

Equilibrium in the labor markets requires that the quantity of each category of labor employed in the intermediate good sector must be equal to the supply, hence:

$$LY_{L,t} = s_{L_L}L_{L,t}, \tag{56}$$

$$LY_{H,t} = s_{L_H}L_{H,t}, \tag{57}$$

$$NY_{S,t} = s_{N_S}N_{S,t}, \tag{58}$$

$$NY_{A,t} = s_{N_A}N_{A,t}. \tag{59}$$

Since the final good can be used for private and public consumption and for private and public investments, we have:

$$P_{C,t} = P_{I,t} = P_{E,t} = \left[(1-\alpha_{IMP})P_t^{1-\sigma_{IMP}} + \alpha_{IMP}P_{M,t}^{1-\sigma_{IMP}}\right]^{\frac{1}{1-\sigma_{IMP}}}, \tag{60}$$

and

$$P_{M,t}IMP_t + P_tY_{H,t} = P_{C,t}\left(C_t + C_t^G + I_t + I_t^G\right) \tag{61}$$

where $Y_{H,t}$ denotes the amount of intermediate goods sold in the domestic market, so that $P_tY_{H,t} = P_tY_t - S_tP_{X,t}EXP_t$.

The economy's net foreign asset position denominated in domestic currency evolves as:

$$S_t B_{F,t} = \left(R^*_{t-1} + \rho^F_{t-1}\right) S_t B_{F,t-1} + S_t P_{X,t} EXP_t - P_{M,t} IMP_t, \tag{62}$$

where the risk premium ρ^F_t is assumed to be increasing in the aggregate level of foreign debt. As in Schmitt-Grohé and Uribe (2003) we use the following functional form for the risk premium: $\rho^F_t = -\varphi^F(e^{BR^F_t - BR^F} - 1)$, where φ^F is a positive parameter, $BR^F_t = S_t B_{F,t}/P_t$ and BR^F is the steady state level of net foreign assets in real terms. Clearly, in the steady-state $\rho^F_t = 0$.

The resource constraint of the economy immediately follows:

$$\begin{aligned} Y_t \quad = \quad & \frac{P^C_t}{P_t}\left(C_t + C^G_t + I_t + I^G_t\right) + \frac{S_t P_{X,t}}{P_t} EXP_t - \frac{P_{M,t}}{P_t} IMP_t + \\ & + \Gamma_P(P_t) + \frac{P_{M,t}}{P_t}\Gamma_{P_M}(P_{M,t}) + \frac{S_t P_{X,t}}{P_t}\Gamma_{P_X}(P_{X,t}) + \\ & + \Gamma_{L_H}(LY_H) + \Gamma_{L_L}(LY_L) + \Gamma_{N_A}(NY_A) + \Gamma_{N_S}(NY_S) + \\ & + \Gamma_{W^{L_H}}(W^{L_H}_t) + \Gamma_{W^{L_L}}(W^{L_L}_t) + \Gamma_{W^{N_S}}(W^{N_S}_t) + \\ & + \frac{P^I_t}{P_t}\Gamma_{u^K}\left(u^K_t\right) + \frac{P^I_t}{P_t}\Gamma_I\left(I^R_t\right). \end{aligned} \tag{63}$$

The core model is summarized in Appendix B.

4 Parametrization and Model Solution

In this section we summarize the parametrization of the model which is mainly based on calibration, with the exception of the main parameters governing the supply of labor inputs for which we have used the estimates obtained with the microsimulation model EconLav. Specifically, IGEM is calibrated on a quarterly basis in order to match steady-state ratios and some specific features of the Italian economy over the period 2002-2008.

The parametrization is summarized in Tables 1a and 1b. We set the benchmark parameters in line with the existing literature. The discount factor β is equal to 0.99, so to imply an annual real interest rate of 4%. The rates of depreciation of private and public physical capital δ_K, δ_G are set to 0.025 (so to imply a 10% annual depreciation rate of capital). The capital share in the intermediate goods production is equal to 0.3, hence $1 - \alpha_L - \alpha_N = 0.3$, while the labor shares are such that $\alpha_L = \alpha_N = 0.35$. In this version we have opted to not consider the contribution of public capital on production and set $\alpha_G = 0$. The CES parameters σ_L and σ_N are set at 1.4 according to Katz and Murphy (1992) estimates also used in QUEST III for Italy.

The elasticity of substitution between domestic goods in the intermediate sector, θ_Y, is set equal to 5 so to have a steady-state level of net markup equal to 25% which is consistent with the value set in the Italian version of QUEST III with R&D (see D'Auria et al. 2009). Since in IGEM tradeable goods are produced in the intermediate sector, we also set the elasticities of substitution between imported and exported varieties, θ_{IMP} and θ_{EXP}, at 5.

The contribution of imported intermediate goods to the final good production, summarized by the parameter α_{IMP} is equal to 0.26, consistently with QUEST III, while the elasticity of substitution between domestic and foreign intermediate varieties σ_{IMP} is set at 1.1. The habit persistence parameter of Ricardian households, h_{C^R}, is set to 0.7 as in QUEST III (see Ratto et al. 2009), while that of non Ricardian households, $h_{C^{NR}}$, is set at 0.3. This different setting in habit persistence between Ricardian and non Ricardian households reflects their relative ability to change their consumption profile over time in response to shocks. The values we set for the habit formation parameters are consistent with the estimates of Sommer (2007).

For simplicity, in this version, the steady-state inflation is set equal to zero, $\Pi = 1$, and we assume full backward indexation of prices and wages, $\kappa_P = \kappa_W = 1$.

Using the RCFL - ISTAT 2008 data, labor categories are defined as follows. Employees are identified with those workers with a stable labor contract and eligible of employment protection, so belonging to the primary labor market. According to the available data, this category amounts to 53% of the whole workforce. In turn, within this category the share of the employees with tertiary education corresponds to the skilled workers and represents 11% of the workers (i.e. $s_{L_H} = 0.11$), while the remaining share is identified with the unskilled employees (i.e. $s_{L_L} = 0.42$). According to the same data, the share of self-employed workers older than 35, is 21% and we set the model share s_{N_S} accordingly. As a matter of fact, we exclude from this category of workers the young, since at early stages of their careers they tend to be precarious and face the same difficulties of the workers with atypical contracts. Hence, the last category of workers labeled as "atypical" includes young self-employed, apprentices, temporary workers and other workers with atypical contracts characterized by weak security protection and low firing costs, so belonging to the secondary market. According to the data this residual fraction of workers amounts to 26% (i.e. $s_{N_A} = 0.26$). In this version of the model we assume that non Ricardian households supply only atypical labor (i.e. $\lambda_{L_L} = 0$), hence $s_{N_R} = 0.26$.

The tax system calibration points to heavy taxation on capital and labor income, where different rates are considered for each labor category. The tax rate on consumption τ^C is equal to 0.17, while the tax rate on physical capital τ^K is 0.33, consistently with the calibration used in the Italian version of QUEST III (see D'Auria et al. 2009). For the tax rates on wage income the calibration is based on the data taken from RFCL - ISTAT 2008. In particular, the average tax rate on labor income paid by skilled employees τ^{L_H} is equal to 0.27, that for the unskilled, τ^{L_L} is set at 0.24, for the self-employed τ^{N_S} is 0.26 and for the atypical workers τ^{N_A} is 0.24. The social contribution rates paid by firms and workers are set, respectively, at 0.33 and 0.09 as legal rates of contribution. Turning to the parameters characterizing the labor markets, according to the estimates based on EconLav microsimulation model, the Frisch elasticity of labor supply for the employees is 0.30, while for the atypical component of the labor force the Frisch elasticity is equal to 0.35. For the self-employed workers we set the Frisch elasticity at 0.30, since we conjecture that the reactivity of their labor supply to changes in their remuneration is closer to that experienced by workers with stable contracts. The elasticities of substitution between different varieties of labor σ_{L_L}, σ_{L_H}, σ_{N_S} are all set at 2.65 in line with the literature (see Forni et al. 2010), reflecting the limited competition protecting the insiders. The elasticities of substitution in the CES aggregators (18) and (19), σ_L, σ_N, are both set at 1.4.

On the grounds that workers with stable contracts tend to be more prone to accumulate skills and human capital than temporary workers, as emphasized by the empirical literature (see Boeri and Garibaldi 2007 among others), the CES parameters measuring efficiencies are calibrated to capture this aspect. In particular, efficiencies are set so as to generate a skill premium for skilled workers (those with tertiary education only) of 50% with respect to the unskilled (consistently with AMECO 2005 data on labor compensations). Also for self-employed we assume a 50% higher remuneration than that granted to the atypical workers.

Turning to the main ratios, the private consumption share C/Y is set at 0.57, the investment share I/Y at 0.18, the public consumption share G/Y at 0.20. Finally, the public debt to output ratio B/PY is set at 1.20 on annual basis.

Finally, the monetary policy parameters are set consistently with the literature. In particular, to account for the fact that Italy is in a monetary union, the coefficients of the interest rate rule can be set so as to reflect the attenuated response of the euro area policy to changes in the economic conditions of the Italian economy.[12]

However, since the aim of this paper is mainly the validation of the model and the presentation of its main characteristics, when studying the dynamic response of the economy to temporary shocks, we will also consider some monetary rules commonly adopted in the literature on business cycle, so as to make our results more comparable to other DGE models. In particular, we will work under the assumptions of a standard Taylor rule ($\iota_R = 0$, $\iota_\Pi = 1.5$, $\iota_Y = 0.125$, $\iota_S = 0$), a weighted Taylor rule in which policy parameters are weighted by the relative size of the Italian economy and an interest rate peg ($\iota_R = \iota_\Pi = \iota_Y = \iota_S = 0$).[13] For the modified Taylor rule the weight is equal to the share of the Italian GDP in the Euro Area according to 2012 Ameco data, i.e. 0.16.

IGEM is implemented in a TROLL platform which uses a Newton-type algorithm to solve non-linear deterministic models.[14] The decision rules of the model are expressed in levels, because we are often interested in simulating the long-run effects of certain policy measures and see what happens in a new steady state. Notably, in the context of forward-looking models analyzing the effects of a permanent shock involving a new steady state requires solving a two-point boundary-problem, specifying the initial conditions for the predetermined variables as well as the terminal conditions for the forward looking variables. While the determination of the initial conditions is straightforward, since these are invariants to shocks, the determination of the terminal conditions may be more difficult especially in large models. The more rigorous approach to solve this problem would make it necessary to derive the new steady state of the model and use the theoretical equilibrium values as terminal conditions, however, in some circumstances, this solution strategy can be taxing. Alternatively, one may opt to reformulate the problem so that the terminal conditions are invariant to policy changes, as proposed by

[12]On this point see Dornbusch et al. (1998).

[13]In the limiting case of interest rate peg the exchange-rate behaviour is fully governed by the Euler equations, related to domestic and foreign assets, and by the time path of foreign assets which affect the risk premium ρ_t^F.

[14]See Hollinger (1996).

Roeger and in't Veld (1999). In this paper we have opted for the latter strategy.

5 Simulation Exercises

In this section, we undertake several simulation exercises in order to validate the model and discuss its properties. In particular, we examine how some key macrovariables respond to a range of temporary shocks typically considered in the literature and to a set of permanent shocks and policy interventions so as to simulate the implementation of structural reforms.

5.1 Response to Temporary Shocks

We start by considering the dynamic properties in response to a temporary increase in productivity, in government consumption and in the nominal interest rate. We show the impulse response functions for a set of selected variables (output, consumption, investments, labor, real wage, inflation rate, nominal interest rate and terms of trade - defined as the domestic export price relative to the import price in domestic currency) over 15 quarters under alternative interest rate rules (Taylor rule, weighted Taylor rule and interest rate peg). All results are reported as percentage deviations from the initial steady-state, except the inflation and the nominal interest rates for which results are expressed as percentage-point deviations.

5.1.1 A Temporary Exogenous Productivity Improvement

Figure 1 shows the impulse response functions to a 1% temporary increase in total factor productivity under a Taylor rule (continuous lines), a weighted Taylor rule (dotted lines) and an interest rate peg (dashed line). The shock equation has an autocorrelation coefficient set at 0.85. As expected, an increase in total factor productivity unambiguously raises output, consumption, investments and real wages, but worsens the terms of trade, so putting upward pressure on relative import prices. Labor hours initially decline, then increase and finally return to the initial level. Intuitively, the increase in total factor productivity enables firms to produce more for a given level of inputs. However, immediately after the shock, as the result of price stickiness, aggregate demand cannot expand accordingly. In this sense, the slow price reaction to current economic conditions, due to the presence of adjustment costs, encourages firms to take advantage of the productivity increase by reducing labor demand. Moreover, an increase in productivity is deflationary. Clearly, the higher productivity brings about a fall in firms' marginal costs, so pushing down the inflation rate.

The magnitude of the effects crucially depends on the response of the monetary policy and so on the behavior of the real interest rates. The fall in inflation is associated with a more than proportional fall in the nominal interest rate when monetary policy is conducted according to a standard Taylor rule, so that the real interest rate also falls. In this case, in fact, the monetary authority accommodates the productivity shock. Under a weighted Taylor rule and under a peg, instead, the reaction to current inflation is milder or null, so that the real interest rate is higher, so explaining why during the early stages of the adjustment the positive effects on output, consumption and investments are more attenuated.

5.1.2 A Temporary Increase in Public Consumption

Figure 2 shows the responses of the eight selected variables to a 1% temporary increase in government consumption under the three interest rate rules. Again we assume that the shock is very persistent with an autocorrelation coefficient set at 0.85.

As a result of the higher demand and price stickiness, output will expand. At the same time, higher government spending crowds out consumption and investments, while labor hours increase and the terms of trade improve, leading to a substitution towards imported goods in the short run. The higher demand brings about an increase in inflation.

It should be noted that in this model a government spending shock generates a negative, albeit negligible, effect on private consumption, despite the presence of an empirically-realistic fraction of liquidity-constraint households, whose consumption is, instead, crowded in by the spending expansion.

The reaction of the monetary authorities will affect the magnitude of the effects. Intuitively, when a Taylor rule is considered, the monetary authorities give more weight to current economic conditions, so being able to better stabilize output and inflation. Conversely, under a peg or a weighted Taylor rule, the increase in government consumption is accommodated and both inflation and output deviate more from their long-run level.

5.1.3 A Monetary Policy Shock

In this experiment we show the impact of a 1% shock hurting the nominal interest rate rule (54). This shock is designed to illustrate how the economy behaves in response to an expected increase in the nominal interest rate. We assume that the shock is sightly persistent, setting the autocorrelation coefficient equal to 0.3. Figure 3 shows the reaction of the key macroeconomic variables to the monetary tightening. As a result of this contractionary shock the economic activity declines and so consumption, investments and hours. The inflation rate will fall, while the terms of trade will worsen.

There are two transmission mechanisms by which the monetary shock is able to affect the level of economic activity. The first channel operates through the higher real interest rate. Due to price rigidities, the high nominal interest rates will increase real interest rates as well so lowering both private consumption and investment and reducing aggregate demand and output. This will, in turn, reduce the demand for labor inputs, exerting a downward pressure on nominal wages and on prices. The net of effects on the real wage will depend on the different degrees of wage and price rigidities.

The second channel operates through the worsening in the terms of trade, leading to an expenditure switching effect, in favor of imported goods, further reducing aggregate demand and the level of output.

5.2 Reform Scenarios

In this section we examine some illustrative scenarios of structural reforms, with particular emphasis on labor market interventions, in order to show the main characteristics of the model and explore its potential as a policy simulation tool.

In particular, we quantify the potential macroeconomic impact of the following exogenous shocks and policy interventions: (i) a permanent exogenous productivity improvement; (ii) a markup reduction in the product market; (iii) markup reductions in the labor markets; (iv) overhead labor reduction; (v) tax shifts from labor to consumption.[15]

All policy changes are assumed to be permanent, as common practice in applied economic modeling when exploring the long-run effects of policy interventions. We have run simulations under the assumption that all changes are unanticipated and take place immediately according to the so called "big bang" hypothesis.[16] In these simulations the interest rate rule is switched off.

All simulation results are reported as percentage deviations from the initial steady-state except for foreign assets and public debt to output ratios for which results are expressed as percentage-point deviations. In this case results are annualized and we extend the time horizon to 100 years.

5.2.1 A Permanent Exogenous Productivity Improvement

In this section we consider the effects of an exogenous and permanent improvement of the TFP. Table 2 presents the results of a permanent increase in A_t by 1 percentage point in the production function (17). A higher level of productivity has unambiguously positive effects on output, consumption and investments, while the effects on aggregate labor are slightly negative. Actually, in the labor markets the improved productivity induces wage setters to set higher wages. In particular, those categories of workers whose level of hours is higher on the baseline will experience a drop in the level of hours worked. On the contrary labor of atypical workers will be positively affected by a TFP improvement. On the supply side, in fact, the initial lower level of hours worked makes this category of workers more sensitive to wage variations. The Frisch elasticity is, in fact, slightly higher than that of the other categories. On the demand side firms face lower adjustment costs when hiring and firing atypical workers. In addition, due to the increased productivity firms can now produce by employing less labor inputs. This cost factor makes producers more prone to substitute employees and self-employed with atypical workers. Finally, the real depreciation of the currency boosts exports; despite the terms of

[15] See Annicchiarico et al. (2013) for a similar exercise using QUEST III with R&D calibrated for Italy, while Lusinyan and Muir (2013) evaluate the macroeconomic impact of some structural reforms in the context of an overlapping generations DGE model for Italy.

[16] Of course, the case of immediate implementation is expected to be an upper bound of the possible effects deriving from single policy interventions. Usually, a period of 5 years represents a realistic time span for a reasonably smooth implementation timetable, while a 10-year gradual introduction may motivated by the possible delays due to the lack of social consensus and/or weak political commitment.

trade loss, after an initial decline imports increase as a result of the higher demand for final goods.

5.2.2 A Markup Reduction in the Product Market

Interventions improving competition and ameliorating the business environment in the product market can be simulated as a reduction in the gross markup of prices over marginal costs in the intermediate goods sector by increasing the elasticity of substitution between pairs of different varieties θ_Y (see equation 25).

Table 3 reports the effects of a 10 percentage point reduction of the price markup. As expected, a reduction of the markup is conducive to a higher level of economic activity and is associated with higher levels of labor, in particular of the atypical workers whose labor supply is more elastic. In addition, lower prices unambiguously raises real wages. As the markup becomes lower, firms will, in fact, increase labor demand. In the long run output rises by 3.80%, investments by 9.06% and consumption by 2.63%. The real depreciation leads exports to increase by 3.54%. The higher level of domestic absorbtion boosts imports by 0.31%. The terms of trade deterioration partially mitigates the positive effects on investments and consumption. Finally, the higher level of output and of fiscal revenues lead to a lower public debt to output ratio.

5.2.3 Markup Reductions in the Labor Markets

IGEM is characterized by the presence of monopolistically competitive labor markets, in which trade unions (for the employees), professional orders (for the self-employed workers) act as wage setters and charge a wage markup over the reservation wage for each differentiated labor input within each category of workers. Wage markups, in turn, negatively depend on the degree of substitutability between the differentiated labor services within each category of workers (see equations 13-15).

Institutional reforms reducing the market power of wage setters generate beneficial results on output, employment, consumption and investments. Table 4 presents the effects of a 10 percentage-point reduction of the wage markup for skilled and unskilled employees and for self-employed. Output immediately jumps and employment increases, following the decline in the real wage as labor supply raises. In the long run the overall effect on output amounts to 1.04%. The higher level of output and the lower labor costs, due to the wage moderation, induce lower prices of domestic production, so boosting exports. Imports will also be higher as a result of the higher level of domestic absorption. It should be noted that, already during the first years of the implementation of the policy, the expansion in the economic activity also leads to an increase in labor of atypical workers who supply labor services under perfect competition.

In general, lowering the markup reduces wages and gradually raises hours for all the four categories of workers. This result can be easily explained when considering the impact of this policy intervention on the different categories of workers. As a matter of fact, we observe some important differences. First, the positive effect on hours worked is higher for the employees and the self-employed who are directly involved by the wage moderation policy. These two categories of workers will ultimately experience lower real remunerations and higher gains in terms of hours worked. By contrast, atypical workers will work more, but at the same time they will benefit from a higher wage. Intuitively, the increased level of hours worked of the other categories of workers together with a higher level of physical capital will boost the marginal productivity of labor of the atypical workers. In other words, the expansion of the economic activity also increases the demand for atypical labor inputs. Of course, the magnitude of these effects will be much lower than those experienced by the other categories of workers, since atypical workers are only indirectly responding to the changed economic conditions.

Tables 5-7 report simulation results under the assumption that the markup is reduced, separately, for single categories of workers, namely the unskilled, the skilled employees and the self-employed. Overall, the effects on output are always unambiguously positive, although much lower when the markup is cut for the skilled workers who represent a small fraction of the workforce. The cumulative long-run effect of output ranges in fact from 0.08% to 0.51%. As expected, for the category involved in the wage moderation policy, hours worked increase and real wages decrease, while we still observe important spillovers effects for the other workers.

Reducing the wage markup of the unskilled workers by 10 pp gives rise to an increase in their hours worked equal to 1.18%, while reducing that of skilled and self-employed by 0.17% and 0.06%, respectively. Hours for the atypical workers will instead increase by 0.09%. The real wage of the unskilled will be reduced by 0.76%, while all the other categories will experience an increase in their real remuneration. Now this different response of the atypical workers can be explained as follows. First, unskilled workers account for more than 40% of the labor force, hence a markup reduction for this category will, on the one hand, boost greatly the marginal productivity of labor inputs supplied by the other categories of workers, on the other, it will induce a substitution across categories. However, workers, supplying labor in a perfectly competitive fashion and under flexible wages, will behave procyclically and both the wage and and the level of hours worked will increase. Skilled workers and self-employed, instead, will react to the new economic conditions by setting a higher remuneration, which will imply a lower level of worked hours. Of course the magnitude of these changes depend on the degree of substitutability between categories of workers (i.e. skilled workers will assist to a larger reduction of their worked hours and to a lower increase in their real wage than self-employed).

The spillovers effects on the other labor markets deriving from a wage moderation policy for skilled employees are qualitatively similar, albeit their magnitude is more attenuated. Again we observe that workers in the perfectly competitive market will work more and at a higher wage, contrary to the unskilled and the self-employed who will work less, but at a higher remuneration, whilst the increase in the real wage is higher for the labor input not directly substitutable with the labor inputs involved by the reform.

Finally, a cut in the markup of self-employed gives rise to more hours worked for this category of 1.19%, while diminishing by 0.06% those of the unskilled and the skilled and increasing by

0.01% those of the atypical workers. In the long run, the real remuneration will be lower by 0.80%, while all the categories will experience slightly higher real wages.

5.2.4 Overhead Labor Reduction

Policy interventions aimed at reducing the administrative and regulatory burden, improving the efficiency of public administration services and favoring the economic activity, are introduced into the model by a decrease of the overhead labor components OH_t^L and OH_t^N in (17). A large amount of time spent with administrative duties and government bureaucracy may hinder economic activity and account for severe barriers to entry. It is then logical that a reduction in the overhead labor is beneficial for firms since it diminishes average production costs.

Table 8 presents the macroeconomic impact of a reduction by 10% in the overhead labor. Overall, we observe that such policy has a positive effects on output, with a cumulative effect of 0.98%, consumption and investments, but negative on labor. Intuitively, since less overhead labor is needed for production, labor demand will now be lower. The higher level of investments is not sufficient to offset the negative effect on labor of the different categories of workers, with the exception of atypical workers, whose labor supply is more elastic and who behave procyclically. Contrary to the other three categories of workers, atypical workers supply labor services in a perfectly competitive fashion, so that the lower demand of labor inputs translates into changes in wages rather than changes in labor hours. On the other hand, workers operating in imperfectly competitive markets will find it optimal to respond to a decline in labor demand by initially increasing their remuneration in the attempt of preserving their labor income, so exacerbating the negative impact on hours. In the long run the effects on work remuneration is negligible for the employees and slightly negative for the self-employed (as a consequence of the lower reduction of the hours worked accruing to the atypical).

In addition, following the domestic production expansion, the terms of trade will slightly deteriorate and exports will increase by more than imports, so improving the net external position of the economy. The worsening of the terms of trade will moderate the positive effects on consumption and investments.

5.2.5 Tax Shifts from Labor to Consumption

In this Section we analyze the macroeconomic implications of a tax shifts from direct to indirect taxation. In particular, we consider a tax shift equal to 1% of output (baseline level) from labor income to consumption, so that the scenario is constructed to be ex-ante budget neutral. In doing so, we will consider tax shifts involving all workers simultaneously. Intuitively, shifting the burden of taxation from direct taxes towards indirect taxes reduces distortions on employment decisions and provide more incentives to labor market participation.

The larger participation to the labor market, in turn, by expanding the level of economic activity and improving the economic prospects, is able to raise investments.

Table 9 reports the response of the main macrovariables to a tax shift from labor income to consumption involving the fours categories of workers. Output will increase by 0.26%, as well as investments and aggregate consumption. However, the higher consumption tax rate will hurt non Ricardian households, who would experience a drop in consumption. High indirect taxes would, in fact, raise the price of goods and services consumed, so diminishing non Ricardian workers' real income. This can be easily explained by observing that, in this policy experiment, transfer recipients, who pay the indirect taxes, are not compensated by the transfers received and that the change in the tax rates, designed to be ex-ante budget neutral for the public sector, is instead biased for the budget balance of non Ricardian households. Putting it in other words, this tax policy involuntarily shifts the burden of taxes disproportionately to the side of non Ricardian households. Turning to the effects on labor, we observe a stronger effect on the hours worked of the atypical workers whose labor supply is more sensitive to changes in their after-tax wage. As a result of the new tax regime real (gross) wages will initially drop, especially for atypical workers whose remuneration is flexible. In the long run the observed higher positive impact on work hours of the atypical comes along with a larger decline of their (gross) wage, due to the decreasing returns of labor.

Finally, the impact on the public sector finances depends on many factors. Overall we observe a slight reduction of the public debt to output ratio due to the overall increase in the tax base.

6 Conclusions

In this paper we have presented IGEM, a new dynamic general equilibrium model for the Italian economy, developed at Department of Treasury of the Italian Ministry of the Economy and Finance. IGEM will serve as a laboratory for studying the macroeconomic implications of actual and hypothetical policy scenarios and will be used in conjunction with the other simulation tools available at the Department of Treasury.

IGEM describes an economy characterized by a large number of nominal and real frictions and distortions. In particular, the model has several fiscal policy variables and features a quite detailed labor market in which different categories of workers coexist. From this point of view the setup is appropriate for the quantitative analysis of fiscal policy interventions and labor market reforms.

To understand the functioning of IGEM and exemplify its potential, we have presented the results of a number of temporary shocks and policy reform scenarios usually examined in the evaluation exercises of structural reforms. IGEM seems to perform well along several dimensions and therefore it seems well suited for policy analysis. Of course, model development is a long-term and continuous process. The version of the model presented in this paper constitutes a first step to be extended in the future along several dimensions.

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Appendix A

Solution to the Households' Problem

Defining as λ_t^R the Lagrange multiplier associated to the budget constraint (9) expressed in real terms, and ξ_t to the capital accumulation equation (6), the first-order conditions for maximization of the lifetime utility function (3) with respect to C_t^R, B_t^R, $B_{F,t}^R$, I_t^R, K_{t+1}^R and u_t^K are given by:

$$\frac{1}{C_t^R - h_{C^R}\overline{C}_{t-1}^R} = (1+\tau_t^C)\frac{P_{C,t}}{P_t}\lambda_t^R, \tag{64}$$

$$\frac{\lambda_t^R}{P_t} = \beta E_t \frac{\lambda_{t+1}^R}{P_{t+1}} R_t, \tag{65}$$

$$S_t \frac{\lambda_t^R}{P_t} = \beta E_t \frac{\lambda_{t+1}^R}{P_{t+1}} (R_t^* + \rho_t^F) S_{t+1}, \tag{66}$$

$$q_t - 1 = \gamma_I \left(\frac{I_t^R}{K_t^R} - \delta_K \right) - tcr_t^K, \tag{67}$$

$$q_t = \beta E_t \frac{\lambda_{t+1}^R}{\lambda_t^R} \frac{\Pi_{t+1}^I}{\Pi_{t+1}} \left[\begin{array}{c} (1-\tau_{t+1}^K) r_{t+1}^K u_{t+1}^K + \tau_{t+1}^K u_{t+1}^K \delta_K \\ + q_{t+1}(1-\delta_K) + \\ -\frac{\gamma_I}{2}\left(\frac{I_{t+1}^R}{K_{t+1}^R} - \delta_K\right)^2 + \gamma_I \left(\frac{I_{t+1}^R}{K_{t+1}^R} - \delta_K\right)\frac{I_{t+1}^R}{K_{t+1}^R} + \\ -\gamma_{u_1^K}\left(u_{t+1}^K - 1\right) - \frac{\gamma_{u_2^K}}{2}\left(u_{t+1}^K - 1\right)^2 \end{array} \right] + \tag{68}$$

$$(1-\tau_t^K) r_t^K + \tau_t^K \delta_K - \gamma_{u_1^K} - \gamma_{u_2^K}\left(u_t^K - 1\right) = 0, \tag{69}$$

where $\Pi_t = P_t/P_{t-1}$, $\Pi_t^I = P_{I,t}/P_{I,t-1}$ and $q_t = \frac{\xi_t}{\lambda_t^R}\frac{P_t}{P_t^I}$ represents the shadow price of a unit of investment good (i.e. the Tobin's q).

The representative hand-to-mouth household chooses consumption and the supply of atypical labor services so as to maximize (10) given (11). We denote by λ_t^{NR} the Lagrange multiplier of the budget constraint expressed in real terms. The optimal conditions with respect to C^{NR} and N_A are then given by:

$$\frac{1}{C_t^{NR} - h_{C^{NR}}\overline{C}_{t-1}^{NR}} = (1+\tau_t^C)\frac{P_{C,t}}{P_t}\lambda_t^{NR}, \tag{70}$$

$$\omega_{N_A}(1-N_{A,t})^{-\upsilon_{N_A}} = \lambda_t^{NR}\left(1-\tau_t^{N_A} - \tau_{h,t}^{W^{N_A}}\right)\frac{W_t^{N_A}}{P_t}. \tag{71}$$

Wage Setting

The monopolistic professional order sets $W_t^{N_S}(h_{N_{S,t}})$ in order to maximize households' expected utility (3), given the demand for its differentiated labor services and subject to a convex adjustment costs function (12). At the optimum and imposing symmetry across differentiated labor services supplied as self-employed we have that the following condition must hold:

$$
\begin{aligned}
0 = {} & \omega_{N_S}\sigma_{N_S}\left(1-N_{s,t}(h_{N_S})\right)^{-\upsilon_{N_S}} N_{s,t}(h_{N_S}) + \\
& -\left(\sigma_{N_S}-1\right)\lambda_t^R\left(1-\tau_t^{N_S}-\tau_{h,t}^{W^{N_S}}\right)N_{s,t}(h_{N_S})\frac{W_t^{N_S}(h_{N_S})}{P_t} \\
& -\lambda_t^R\gamma_{W^{N_S}}\left(\frac{1}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{W_t^{N_S}(h_{N_S})}{W_{t-1}^{N_S}(h_{N_S})}-1\right)\frac{1}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{W_t^{N_S}(h_{N_S})}{W_{t-1}^{N_S}(h_{N_S})}Y_t + \\
& +\beta E_t\lambda_{t+1}^R\gamma_{W^{N_S}}\left(\frac{1}{\Pi_t^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{W_{t+1}^{N_S}(h_{N_S})}{W_t^{N_S}(h_{N_S})}-1\right)\frac{1}{\Pi_t^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{W_{t+1}^{N_S}(h_{N_S})}{W_t^{N_S}(h_{N_S})}Y_{t+1}.
\end{aligned}
\tag{72}
$$

In steady state, given symmetry, (72) boils down to (13).

For skilled labor services at the optimum the wage setting equation reads as:

$$
\begin{aligned}
0 = {} & \omega_{L_H}\sigma_{L_H}\left(1-L_{H,t}\right)^{-\upsilon_{L_H}} L_{H,t} + \\
& -\left(\sigma_{L_H}-1\right)\lambda_t^R\left(1-\tau_t^{L_H}-\tau_{h,t}^{W^{L_H}}\right)L_{H,t}\frac{W_t^{L_H}}{P_t} + \\
& -\lambda_t^R\gamma_{W^{L_H}}\left(\frac{1}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{W_t^{L_H}}{W_{t-1}^{L_H}}-1\right)\frac{1}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{W_t^{L_H}}{W_{t-1}^{L_H}}Y_t + \\
& +\beta E_t\lambda_{t+1}^R\gamma_{W^{L_H}}\left(\frac{1}{\Pi_t^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{W_{t+1}^{L_H}}{W_t^{L_H}}-1\right)\frac{1}{\Pi_t^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{W_{t+1}^{L_H}}{W_t^{L_H}}Y_{t+1}.
\end{aligned}
\tag{73}
$$

which in steady state gives (14).

Finally, the first-order condition for wage setting for unskilled labor services, after having imposed symmetry is:

$$
\begin{aligned}
0 = {} & \omega_{L_L}\sigma_{L_L}\left(1-L_{L,t}\right)^{-\upsilon_{LL}} L_{L,t} + \\
& -\left(\sigma_{L_L}-1\right)\left(1-\tau_t^{L_L}-\tau_{h,t}^{W^{L_L}}\right)[(1-\lambda^{L_L})\lambda_t^R+\lambda^{L_L}\lambda_t^{NR}]L_{L,t}\frac{W_t^{L_L}}{P_t} + \\
& -\left[(1-\lambda^{L_L})\lambda_t^R+\lambda^{L_L}\lambda_t^{NR}\right]\gamma_{W^{L_L}}\left(\frac{1}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{W_t^{L_L}}{W_{t-1}^{L_L}}-1\right)\frac{1}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{W_t^{L_L}}{W_{t-1}^{L_L}}Y_t + \\
& +\beta\left[(1-\lambda^{L_L})\lambda_{t+1}^R+\lambda^{L_L}\lambda_{t+1}^{NR}\right]\gamma_{W^{L_L}}\left(\frac{1}{\Pi_t^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{W_{t+1}^{L_L}}{W_t^{L_L}}-1\right)\frac{1}{\Pi_t^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{W_{t+1}^{L_L}}{W_t^{L_L}}Y_{t+1}.
\end{aligned}
\tag{74}
$$

In steady state the above condition becomes (15).

Solution to the Intermediate Producers Problem

Given technology, the adjustment costs on price setting (20) and on labor inputs (21)-(24) and the demand schedule for its own variety j, $Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\theta_Y} Y_t$ firm j will make choices about the price and labor inputs, so as to maximize the present discounted value of future profits. At the optimum and under symmetry we have the optimal pricing decision equation which describes the time path of domestic inflation Π_t:

$$
\begin{aligned}
&\left[(1-\theta_Y)+MC_t\theta_Y\right]Y_t+ \\
&\qquad -\gamma_P\left(\frac{\Pi_t}{\Pi_{t-1}^{\kappa_P}\overline{\Pi}^{1-\kappa_P}}-1\right)\frac{\Pi_t}{\Pi_{t-1}^{\kappa_P}\overline{\Pi}^{1-\kappa_P}}Y_t+ \\
&\qquad\qquad +\beta\gamma_P E_t\frac{\lambda_{t+1}^R}{\lambda_t^R}\left(\frac{\Pi_{t+1}}{\Pi_t^{\kappa_P}\overline{\Pi}^{1-\kappa_P}}-1\right)\frac{\Pi_{t+1}}{\Pi_t^{\kappa_P}\overline{\Pi}^{1-\kappa_P}}Y_{t+1}=0,
\end{aligned}
$$

and the demand for unskilled and skilled employees, atypical workers and labor services provided by self-employed workers are:

$$
\begin{aligned}
&\frac{W_t^{L_L}}{P_t}\left(1-sub_t^{L_L}+\tau_{f,t}^{W^{L_L}}\right)= \\
&\qquad \alpha_L\left(1-\alpha_G\right)MC_t\left(j\right)\frac{Y_t\left(j\right)}{L_{CES,t}(j)-OH_t^L}\left(\frac{L_{CES,t}(j)}{LY_{L,t}(j)}\right)^{\frac{1}{\sigma_L}}s_{L_L}^{\frac{1}{\sigma_L}}ef_{L_L}^{\frac{\sigma_L-1}{\sigma_L}}+ \\
&-\gamma_{L_L}\left(\frac{LY_{L,t}\left(j\right)}{LY_{L,t-1}\left(j\right)}-1\right)Y_t\frac{1}{LY_{L,t-1}\left(j\right)}+\beta\frac{\lambda_{t+1}^R}{\lambda_t^R}\gamma_{L_L}\left(\frac{LY_{L,t+1}\left(j\right)}{LY_{L,t}\left(j\right)}-1\right)Y_{t+1}\frac{LY_{L,t+1}\left(j\right)}{LY_{L,t}\left(j\right)^2},
\end{aligned}
$$

$$
\begin{aligned}
&\frac{W_t^{L_H}}{P_t}\left(1-sub_t^{L_H}+\tau_{f,t}^{W^{L_H}}\right)= \\
&\qquad \alpha_L\left(1-\alpha_G\right)MC_t\left(j\right)\frac{Y_t\left(j\right)}{L_{CES,t}(j)-OH_t^L}\left(\frac{L_{CES,t}(j)}{LY_{H,t}(j)}\right)^{\frac{1}{\sigma_L}}s_{L_H}^{\frac{1}{\sigma_L}}ef_{L_H}^{\frac{\sigma_L-1}{\sigma_L}}+ \\
&-\gamma_{L_H}\left(\frac{LY_{H,t}\left(j\right)}{LY_{H,t-1}\left(j\right)}-1\right)Y_t\frac{1}{LY_{H,t-1}\left(j\right)}+\beta\frac{\lambda_{t+1}^R}{\lambda_t^R}\gamma_{L_H}\left(\frac{LY_{H,t+1}\left(j\right)}{LY_{H,t}\left(j\right)}-1\right)Y_{t+1}\frac{LY_{H,t+1}\left(j\right)}{LY_{H,t}\left(j\right)^2},
\end{aligned}
$$

$$
\begin{aligned}
&\frac{W_t^{N_A}}{P_t}\left(1-sub_t^{N_A}+\tau_{f,t}^{W^{N_A}}\right)= \\
&\qquad \alpha_N\left(1-\alpha_G\right)MC_t\left(j\right)\frac{Y_t\left(j\right)}{N_{CES,t}(j)-OH_t^N}\left(\frac{N_{CES,t}(j)}{NY_{A,t}(j)}\right)^{\frac{1}{\sigma_N}}s_{N_S}^{\frac{1}{\sigma_N}}ef_{N_S}^{\frac{\sigma_N-1}{\sigma_N}}+ \\
&-\gamma_{N_A}\left(\frac{NY_{A,t}\left(j\right)}{NY_{A,t-1}\left(j\right)}-1\right)Y_t\frac{1}{NY_{A,t-1}\left(j\right)}+\beta\frac{\lambda_{t+1}^R}{\lambda_t^R}\gamma_{N_A}\left(\frac{NY_{A,t+1}\left(j\right)}{NY_{A,t}\left(j\right)}-1\right)Y_{t+1}\frac{NY_{A,t+1}\left(j\right)}{NY_{A,t}\left(j\right)^2}.
\end{aligned}
$$

$$
\begin{aligned}
&\frac{W_t^{N_S}}{P_t}\left(1+\tau_{f,t}^{W^{N_S}}\right)=\alpha_N\left(1-\alpha_G\right)MC_t\left(j\right)\frac{Y_t\left(j\right)}{N_{CES,t}(j)-OH_t^N}\left(\frac{N_{CES,t}(j)}{NY_{S,t}(j)}\right)^{\frac{1}{\sigma_N}}s_{N_S}^{\frac{1}{\sigma_N}}ef_{N_S}^{\frac{\sigma_N-1}{\sigma_N}}+ \\
&-\gamma_{N_S}\left(\frac{NY_{S,t}\left(j\right)}{NY_{S,t-1}\left(j\right)}-1\right)Y_t\frac{1}{NY_{S,t-1}\left(j\right)}+\beta\frac{\lambda_{t+1}^R}{\lambda_t^R}\gamma_{N_S}\left(\frac{NY_{S,t+1}\left(j\right)}{NY_{S,t}\left(j\right)}-1\right)Y_{t+1}\frac{NY_{S,t+1}\left(j\right)}{NY_{S,t}\left(j\right)^2}.
\end{aligned}
$$

In steady state the above conditions correspond to (25) and (27)-(30), respectively.

Exporting and Importing Firms

The typical exporting firm will set the exporting price $P_{X,t}(j)$, so as to maximize the expected discounted value of future profits, taking as given the adjustment cost (31), the exchange rate S_t and the world demand for good j $EXP_t(j) = \left(\frac{P_{X,t}(j)}{P_{X,t}}\right)^{-\theta_{EXP}} EXP_t$. At the optimum and imposing symmetry, the price of goods sold in the foreign market obeys to the following law of motion:

$$\begin{aligned}
&\left[(1-\theta_{EXP})\frac{S_t P_{X,t}}{P_t} + \theta_{EXP}\right] EXP_t + \\
&\quad - \gamma_{EXP}\left[\frac{\Pi_{EXP,t}}{\left(\Pi^*_{t-1}\right)^{\kappa_{EXP}}\left(\overline{\Pi}^*\right)^{1-\kappa_{EXP}}} - 1\right]\frac{\Pi_{EXP,t}}{\left(\Pi^*_{t-1}\right)^{\kappa_{EXP}}\left(\overline{\Pi}^*\right)^{1-\kappa_{EXP}}} EXP_t + \\
&\quad + \gamma_{EXP}\beta E_t \frac{\lambda^R_{t+1}}{\lambda^R_t}\left[\frac{\Pi_{EXP,t+1}}{(\Pi^*_t)^{\kappa_{EXP}}\left(\overline{\Pi}^*\right)^{1-\kappa_{EXP}}} - 1\right]\frac{\Pi_{EXP,t+1}}{(\Pi^*_t)^{\kappa_{EXP}}\left(\overline{\Pi}^*\right)^{1-\kappa_{EXP}}} EXP_{t+1} = 0,
\end{aligned}$$

where $\Pi_{EXP,t} = P_{X,t}/P_{X,t-1}$. In steady state the above condition becomes (32).

The importing firm will set its price in local currency as a markup over the import price of intermediate goods produced abroad given the demand $IMP_t(j) = \left(\frac{P_{M,t}(j)}{P^M_t}\right)^{-\theta_{IMP}} IMP_t$ and the adjustment cost function (adjust:imp). At the optimum, we have:

$$\begin{aligned}
&\left[(1-\theta_{IMP})\frac{P_{M,t}}{P_t} + \frac{S_t P^*_t}{P_t}\theta_{IMP}\right] IMP_t \\
&\quad - \gamma_{IMP}\left(\frac{\Pi_{IMP,t}}{\Pi^{\kappa_{IMP}}_{t-1}\overline{\Pi}^{1-\kappa_{IMP}}} - 1\right)\frac{\Pi_{IMP,t}}{\Pi^{\kappa_{IMP}}_{t-1}\overline{\Pi}^{1-\kappa_{IMP}}} IMP_t + \\
&\quad + \gamma_{IMP}\beta E_t \frac{\lambda^R_{t+1}}{\lambda^R_t}\left(\frac{\Pi_{IMP,t+1}}{\Pi^{\kappa_{IMP}}_t\overline{\Pi}^{1-\kappa_{IMP}}} - 1\right)\frac{\Pi_{IMP,t+1}}{\Pi^{\kappa_{IMP}}_t\overline{\Pi}^{1-\kappa_{IMP}}} IMP_{t+1} = 0,
\end{aligned}$$

where $\Pi_{IMP,t} = P_{M,t}/P_{M,t-1}$. In steady state the above condition simplifies to (34).

Appendix B

1 Euler Equation of the Ricardian Households

$\lambda^R_t = \beta E_t \lambda^R_{t+1} \frac{R_t}{\Pi_{t+1}}$

2 Lagrangian Multiplier of the Ricardian Households

$\lambda^R_t = \frac{P_t}{P_{C,t}} \frac{1}{(1+\tau^C_t)\left(C^R_t - h_{C^R} C^R_{t-1}\right)}$

3 Consumption of the Non Ricardian Households

$$C_t^{NR} = \frac{P_t}{\left(1+\tau_t^C\right)P_{C,t}} \left[\begin{array}{c} \left(1-\tau_t^{N_A}-\tau_{h,t}^{W^{N_A}}\right) \frac{s_{N_A}}{s_{NR}} WR_t^{N_A} N_{A,t} - TAX_t^{NR} + \\ +Tr_t^{NR} + \left(1-\tau_t^{L_L}-\tau_{h,t}^{W^{L_L}}\right) \frac{\lambda^{L_L} s_{L_L}}{s_{NR}} WR_t^{L_L} L_{L,t} + \\ -\frac{\lambda^{L_L} s_{L_L}}{s_{NR}} \frac{\gamma_{W^{L_L}}}{2} \left(\frac{1}{\Pi_{t-1}^{\kappa_W} \overline{\Pi}^{1-\kappa_W}} \frac{WR_t^{L_L}}{WR_{t-1}^{L_L}} \Pi_t - 1 \right)^2 Y_t \end{array} \right]$$

4 Lagrangian Multiplier of Non Ricardian Households

$$\lambda_t^{NR} = \frac{P_t}{P_{C,t}} \frac{1}{(1+\tau_t^C)\left(C_t^{NR} - h_{C^{NR}} C_{t-1}^{NR}\right)}$$

5 Aggregate Consumption

$$C_t = s_{NR} C_t^{NR} + (1-s_{NR}) C_t^R$$

6 Wage Equation of Self-Employed Labor Workers

$$\begin{aligned} &(\sigma_{N_S}-1)\,\lambda_t^R \left(1-\tau_t^{N_S}-\tau_{h,t}^{W^{N_S}}\right) WR_t^{N_S} N_{S,t} = \omega_{N_S}\sigma_{N_S}\,(1-N_{S,t})^{-v_{N_S}}\, N_{S,t} + \\ &\quad -\lambda_t^R \gamma_{W^{N_S}} \left(\frac{WR_t^{N_S}}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W} WR_{t-1}^{N_S}} \Pi_t - 1 \right) Y_t \frac{WR_t^{N_S}}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W} WR_{t-1}^{N_S}} \Pi_t + \\ &\quad +\beta\lambda_{t+1}^R \gamma_{W^{N_S}} \left(\frac{WR_{t+1}^{N_S}}{\Pi_t^{\kappa_W}\overline{\Pi}^{1-\kappa_W} WR_t^{N_S}} \Pi_{t+1} - 1 \right) Y_{t+1} \frac{WR_{t+1}^{N_S}}{\Pi_t^{\kappa_W}\overline{\Pi}^{1-\kappa_W} WR_t^{N_S}} \Pi_{t+1} \end{aligned}$$

7 Wage Equation of Skilled Employees

$$\begin{aligned} &(\sigma_{L_H}-1)\,\lambda_t^R \left(1-\tau_t^{L_H}-\tau_{h,t}^{W^{L_H}}\right) WR_t^{L_H} L_{H,t} = \omega_{L_H}\sigma_{L_H}\,(1-L_{H,t})^{-v_{L_H}}\, L_{H,t} + \\ &\quad -\lambda_t^R \gamma_{W^{L_H}} \left(\frac{WR_t^{L_H}}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W} WR_{t-1}^{L_H}} \Pi_t - 1 \right) Y_t \frac{WR_t^{L_H}}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W} WR_{t-1}^{L_H}} \Pi_t + \\ &\quad +\beta\lambda_{t+1}^R \gamma_{W^{L_H}} \left(\frac{WR_{t+1}^{L_H}}{\Pi_t^{\kappa_W}\overline{\Pi}^{1-\kappa_W} WR_t^{L_H}} \Pi_{t+1} - 1 \right) Y_{t+1} \frac{WR_{t+1}^{L_H}}{\Pi_t^{\kappa_W}\overline{\Pi}^{1-\kappa_W} WR_t^{L_H}} \Pi_{t+1} \end{aligned}$$

8 Wage Equation of Unskilled Employees

$$\begin{aligned} &(\sigma_{L_L}-1)\left[(1-I^{NR}\lambda^{L_L})\lambda_t^R + I^{NR}\lambda^{L_L}\lambda_t^{NR}\right]\left(1-\tau_t^{L_L}-\tau_{h,t}^{W^{L_L}}\right) WR_t^{L_L} L_{L,t} = \\ &\quad +\omega_{L_L}\sigma_{L_L}\,(1-L_{L,t})^{-v_{LL}}\, L_{L,t} + \\ &\quad -\left[(1-I^{NR}\lambda^{L_L})\lambda_t^R + I^{NR}\lambda^{L_L}\lambda_t^{NR}\right]\gamma_{W^{L_L}} \left(\frac{WR_t^{L_L}}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W} WR_{t-1}^{L_L}(h_{L_L})} \Pi_t - 1 \right) Y_t \frac{WR_t^{L_L}}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W} WR_{t-1}^{L_L}} \Pi_t + \\ &\quad +\beta\left[(1-I^{NR}\lambda^{L_L})\lambda_{t+1}^R + I^{NR}\lambda^{L_L}\lambda_{t+1}^{NR}\right]\gamma_{W^{L_L}} \left(\frac{WR_{t+1}^{L_L}}{\Pi_t^{\kappa_W}\overline{\Pi}^{1-\kappa_W} WR_t^{L_L}} \Pi_{t+1} - 1 \right) Y_{t+1} \frac{WR_{t+1}^{L_L}}{\Pi_t^{\kappa_W}\overline{\Pi}^{1-\kappa_W} WR_t^{L_L}} \Pi_{t+1} \end{aligned}$$

9 Supply of Atypical Labor Services

$$\frac{1}{\lambda_t^{NR}} = WR_t^{N_A}\,(1-N_{A,t})^{v_{N_A}}\, \frac{1-\tau_t^{N_A}-\tau_{h,t}^{W^{N_A}}}{\omega_{N_A}}$$

10 Demand of Skilled Labor as Employees

$$WR_t^{L_H}\left(1 - sub_t^{L_H} + \tau_{f,t}^{W^{L_H}}\right) = \alpha_L\left(1 - I_X\alpha_G\right)MC_t\frac{X_t}{L_{CES,t} - OH^L}sx_{L_H}^{\frac{1}{\sigma_L}}\left(ef_{L_H}\right)^{\frac{\sigma_L - 1}{\sigma_L}}\left(\frac{L_{CES,t}}{LY_{H,t}}\right)^{\frac{1}{\sigma_L}} +$$
$$-\gamma_{L_H}\left(\frac{LY_{H,t}}{LY_{H,t-1}} - 1\right)Y_t\frac{1}{LY_{H,t-1}} +$$
$$+\beta\frac{\lambda_{t+1}^R}{\lambda_t^R}\gamma_{L_H}\left(\frac{LY_{H,t+1}}{LY_{H,t}} - 1\right)Y_{t+1}\frac{LY_{H,t+1}}{LY_{H,t}^2}$$

11 Demand of Unskilled Labor as Employees

$$WR_t^{L_L}\left(1 - sub_t^{L_L} + \tau_{f,t}^{W^{L_L}}\right) = \alpha_L\left(1 - I_X\alpha_G\right)MC_t\frac{X_t}{L_{CES,t} - OH^L}sx_{L_L}^{\frac{1}{\sigma_L}}\left(ef_{L_L}\right)^{\frac{\sigma_L - 1}{\sigma_L}}\left(\frac{L_{CES,t}}{LY_{L,t}}\right)^{\frac{1}{\sigma_L}} +$$
$$-\gamma_{L_L}\left(\frac{LY_{L,t}}{LY_{L,t-1}} - 1\right)Y_t\frac{1}{LY_{L,t-1}} +$$
$$+\beta\frac{\lambda_{t+1}^R}{\lambda_T^R}\gamma_{L_L}\left(\frac{LY_{L,t+1}}{LY_{L,t}} - 1\right)Y_{t+1}\frac{LY_{L,t+1}}{LY_{L,t}^2}$$

12 Demand of Self-Employed Labor

$$WR_t^{N_S}\left(1 + \tau_{f,t}^{W_{N_S}}\right) = \alpha_N\left(1 - I_X\alpha_G\right)MC_t\frac{Y_t}{N_{CES,t} - OH^N}sx_{N_S}^{\frac{1}{\sigma_N}}\left(ef_{N_S}\right)^{\frac{\sigma_N - 1}{\sigma_N}}\left(\frac{N_{CES,t}}{NY_{S,t}}\right)^{\frac{1}{\sigma_N}} +$$
$$-\gamma_{N_S}\left(\frac{NY_{S,t}}{NY_{S,t-1}} - 1\right)Y_t\frac{1}{NY_{S,t-1}} +$$
$$+\beta\frac{\lambda_{t+1}^R}{\lambda_T^R}\gamma_{N_S}\left(\frac{NY_{S,t+1}}{NY_{S,t}} - 1\right)Y_{t+1}\frac{NY_{S,t+1}}{NY_{S,t}^2}$$

13 Demand of Atypical Labor

$$WR_t^{N_A}\left(1 - sub_t^{N} + \tau_{f,t}^{W^{N_A}}\right) = \alpha_N\left(1 - \alpha_G\right)MC_t\frac{Y_t}{N_{CES,t} - OH^N}sx_{N_A}^{\frac{1}{\sigma_N}}\left(ef_{N_A}\right)^{\frac{\sigma_N - 1}{\sigma_N}}\left(\frac{N_{CES,t}}{NY_{A,t}}\right)^{\frac{1}{\sigma_N}} +$$
$$-\gamma_{N_A}\left(\frac{NY_{A,t}}{NY_{A,t-1}} - 1\right)Y_t\frac{1}{NY_{A,t-1}} +$$
$$+\beta\frac{\lambda_{t+1}^R}{\lambda_T^R}\gamma_{N_A}\left(\frac{NY_{A,t+1}}{NY_{A,t}} - 1\right)Y_{t+1}\frac{NY_{A,t+1}}{NY_{A,t}^2}$$

14 Equilibrium in the Labor Market, Unskilled Employees

$$LY_{L,t} = s_{L_L}L_{L,t}$$

15 Equilibrium in the Labor Market, Skilled Employees

$$LY_{H,t} = s_{L_H}L_{H,t}$$

16 Equilibrium in the Labor Market, Self-Employed Workers

$$NY_{S,t} = s_{N_S}N_{S,t}$$

17 Equilibrium in the Labor Market, Atypical Workers

$$NY_{A,t} = s_{N_A}N_{A,t}$$

18 Labor Aggregate

$$LN_t = s_{L_L}L_{L,t} + s_{L_H}L_{H,t} + s_{N_S}N_{S,t} + s_{N_A}N_{A,t}$$

19 Production Function of the Intermediate-Goods Producers

$$Y_t = A_t \left[\left(L_{CES,t} - OH_t^L \right)^{\alpha_L} \left(N_{CES,t} - OH_t^N \right)^{\alpha_N} \left(u_t^K K_t \right)^{1-\alpha_L-\alpha_N} \right]^{1-\alpha_G} KG_t^{\alpha_G}$$

20 Employees Labor CES Aggregate

$$L_{CES,t} = \left[sx_{L_L}^{\frac{1}{\sigma_L}} \left(ef_{L_L} LY_{L,t} \right)^{\frac{\sigma_L-1}{\sigma_L}} + sx_{L_H}^{\frac{1}{\sigma_L}} \left(ef_{L_H} LY_{H,t} \right)^{\frac{\sigma_L-1}{\sigma_L}} \right]^{\frac{\sigma_L}{\sigma_{L-1}}}$$

21 Self-Employed and Atypical Labor CES Aggregate

$$N_{CES,t} = \left[sx_{N_S}^{\frac{1}{\sigma_N}} \left(ef_{N_S} NY_{S,t} \right)^{\frac{\sigma_N-1}{\sigma_N}} + sx_{N_A}^{\frac{1}{\sigma_N}} \left(ef_{N_A} NY_{A,t} \right)^{\frac{\sigma_N-1}{\sigma_N}} \right]^{\frac{\sigma_N}{\sigma_{N-1}}}$$

22 Physical Capital Accumulation Equation

$$K_{t+1} = (1 - \delta_K) K_t + I_t$$

23 Investment Equation

$$q_t - 1 = \gamma_I \left(\frac{I_t}{K_t} - \delta_K \right) - tcr_t^K$$

24 Tobin's Q

$$q_t = \beta E_t \frac{\lambda_{t+1}^R}{\lambda_t^R} \frac{\Pi_{t+1}^I}{\Pi_{t+1}} \left[(1 - \tau_{t+1}^K) r_{t+1}^K u_{t+1}^K + \tau_{t+1}^K u_{t+1}^K \delta_K + q_{t+1} (1 - \delta_K) \right] +$$
$$-\beta E_t \frac{\lambda_{t+1}^R}{\lambda_t^R} \frac{\Pi_{t+1}^I}{\Pi_{t+1}} \left[\frac{\gamma_I}{2} \left(\frac{I_{t+1}^R}{K_{t+1}^R} - \delta_K \right)^2 - \gamma_I \left(\frac{I_{t+1}^R}{K_{t+1}^R} - \delta_K \right) \frac{I_{t+1}^R}{K_{t+1}^R} + \gamma_{u_1^K} \left(u_{t+1}^K - 1 \right) + \frac{\gamma_{u_2^K}}{2} \left(u_{t+1}^K - 1 \right)^2 \right]$$

25 Demand of Capital

$$r_t^k u_t^K = \frac{P_t}{P_t^I} (1 - \alpha_G)(1 - \alpha_L - \alpha_N) MC_t \frac{Y_t}{K_t}$$

26 Capital Utilization

$$(1 - \tau_t^K) r_t^K + \tau_t^K \delta_K - \gamma_{u_1^K} - \gamma_{u_2^K} \left(u_t^K - 1 \right) = 0$$

27 Real Profits of Intermediate Goods Producers

$$PRO_t = Y_t - WR_t^{L_L} \left(1 - sub_t^L + \tau_{f,t}^{W^L} \right) LY_{L,t} - WR_t^{L_H} \left(1 - sub_t^L + \tau_{f,t}^{W^L} \right) LY_{H,t} +$$
$$-WR_t^{N_S} \left(1 + \tau_{f,t}^{W_{N_S}} \right) NY_{S,t} - WR_t^{N_A} \left(1 - sub_t^N + \tau_{f,t}^{W^{N_A}} \right) NY_{A,t} +$$
$$-\frac{P_t^I}{P_t} r_t^K u_t^K K_t - \frac{\gamma_p}{2} \left(\frac{\Pi_t}{\Pi_{t-1}^{\kappa_P} \overline{\Pi}^{1-\kappa_P}} - 1 \right)^2 Y_t - \frac{\gamma_{L_H}}{2} \left(\frac{LY_{H,t}}{LY_{H,t-1}} - 1 \right)^2 Y_t +$$
$$-\frac{\gamma_{L_L}}{2} \left(\frac{LY_{L,t}}{LY_{L,t-1}} - 1 \right)^2 Y_t - \frac{\gamma_{N_S}}{2} \left(\frac{NY_{S,t}}{NY_{S,t-1}} - 1 \right)^2 Y_t - \frac{\gamma_{N_A}}{2} \left(\frac{NY_{A,t}}{NY_{A,t-1}} - 1 \right)^2 Y_t$$

28 Inflation Equation

$$Y_t - \gamma_p \left(\frac{\Pi_t}{\Pi_{t-1}^{\kappa_P} \overline{\Pi}^{1-\kappa_P}} - 1 \right) Y_t \frac{\Pi_t}{\Pi_{t-1}^{\kappa_P} \overline{\Pi}^{1-\kappa_P}} + \beta \gamma_p E_t \frac{\lambda_{t+1}^R}{\lambda_t^R} \left(\frac{\Pi_{t+1}}{\Pi_t^{\kappa_P} \overline{\Pi}^{1-\kappa_P}} - 1 \right) Y_{t+1} \frac{\Pi_{t+1}}{\Pi_t^{\kappa_P} \overline{\Pi}^{1-\kappa_P}} = (1 - MC_t) \theta_x Y_t$$

29 Accumulation of Public Capital

$$KG_{t+1} = IG_t + (1 - \delta_{KG}) KG_t$$

30 Flow Budget Constraint of the Government

$$B_t = R_{t-1}B_{t-1} + P_{C,t}C_t^G + P_{I,t}I_t^G + P_tTr_t +$$
$$-P_tTAX_t - P_t (LTAX_t + CTAX_t + KTAX_t) + P_tSUB_t$$

31 Transfers

$$Tr_t = s_{NR}Tr_t^{NR} + (1 - s_{NR})Tr_t^R$$

32 Labor Taxes and Social Contributions

$$LTAX_t = s_{L_L}L_{L_L,t}WR_t^{L_L}\left(\tau_t^{L_L} + \tau_{h,t}^{W_{L_L}} + \tau_{f,t}^{W_{L_L}}\right) + s_{L_H}L_{L_H,t}WR_t^{L_H}\left(\tau_t^{L_H} + \tau_{h,t}^{W_{L_H}} + \tau_{f,t}^{W_{L_H}}\right) +$$
$$+s_{N_S,t}L_{N_S,t}WR_t^{N_S}\left(\tau_t^{N_S} + \tau_{h,t}^{W_{N_s}} + \tau_{f,t}^{W_{N_S}}\right) + s_{N_A}L_{N_A,t}WR_t^{N_A}\left(\tau_t^{N_A} + \tau_{h,t}^{W_{N_A}} + \tau_{f,t}^{W_{N_A}}\right)$$

33 Consumption Taxes

$$TVAT_t = \tau_t^C \frac{P_{C,t}}{P_t}\left[s_{NR}C_t^{NR} + (1 - s_{NR})C_t^R\right]$$

34 Capital Taxes Net of Tax Credit

$$KTAX_t = \frac{P_t^I}{P_t}\tau_t^K\left(r_t^K - \delta^K\right)u_t^K K_t - tcr_t^K\frac{P_t^I}{P_t}I_t$$

35 Fiscal Rule

$$P_tTAX_t = P_t\overline{TAX} + T_BB_{t-1} + T_DD_t + T_YP_t(Y_t - Y_{t-1})$$

36 Lump-Sum Taxes Levied on Ricardian Households

$$TAX_t^R = \left(1 - s_{TAX}^{NR}\right)TAX_t$$

37 Lump-Sum Taxes Levied on Non Ricardian Households

$$TAX_t^{NR} = s_{TAX}^{NR}TAX_t$$

38 Labor Subsidies

$$SUB_t = sub_t^{L_L}s_{L_L}L_{L,t}WR_t^{L_L} + sub_t^{L_H}s_{L_H}L_{H,t}WR_t^{L_H} + sub_t^{N}s_{N_A}N_{A,t}WR_t^{N_A}$$

39 Government Deficit

$$D_t = (R_{t-1} - 1)B_{t-1} + P_{C,t}G_t + P_{IG,t}IG_t + P_tTr_t +$$
$$-P_tTAX_t - P_t (LTAX_t + CTAX_t + KTAX_t) + P_tSUB_t$$

40 Resource Constraint of the Economy

$$Y_t = \frac{P_t^C}{P_t}(G_t + C_t) + \frac{P_t^I}{P_t}(I_t + IG_t) + \frac{S_t P_{X,t}}{P_t} EXP_t - \frac{P_{M,t}}{P_t} IMP_t +$$
$$+\frac{\gamma_p}{2}\left(\frac{\Pi_t}{\Pi_{t-1}^{\kappa_P}\overline{\Pi}^{1-\kappa_P}} - 1\right)^2 Y_t + \frac{\gamma_I}{2}\frac{P_t^I}{P_t}\left(\frac{I_t}{K_t} - \delta_K\right)^2 K_t + \frac{\gamma_{L_H}}{2}\left(\frac{LX_{H,t}}{LX_{H,t-1}} - 1\right)^2 Y_t +$$
$$+\frac{\gamma_{L_L}}{2}\left(\frac{LY_{L,t}}{LY_{L,t-1}} - 1\right)^2 Y_t + \frac{\gamma_{N_S}}{2}\left(\frac{NY_{S,t}}{NY_{S,t-1}} - 1\right)^2 Y_t + \frac{\gamma_{N_A}}{2}\left(\frac{NY_{A,t}}{NY_{A,t-1}} - 1\right)^2 Y_t +$$
$$+\frac{\gamma_{W^{L_L}}}{2}\left(\frac{1}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{WR_t^{L_L}}{WR_{t-1}^{L_L}}\Pi_t - 1\right)^2 Y_t + \frac{\gamma_{W^{L_H}}}{2}\left(\frac{1}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{WR_t^{L_H}}{WR_{t-1}^{L_H}}\Pi_t - 1\right)^2 Y_t +$$
$$+\frac{\gamma_{W^{N_S}}}{2}\left(\frac{1}{\Pi_{t-1}^{\kappa_W}\overline{\Pi}^{1-\kappa_W}}\frac{WR_t^{N_S}}{WR_{t-1}^{N_S}}\Pi_t - 1\right)^2 Y_t +$$
$$+\frac{\gamma_{IMP}}{2}\frac{P_{M,t}}{P_t}\left(\frac{\Pi_t^{IMP}}{\Pi_{t-1}^{\kappa_{IMP}}\overline{\Pi}^{1-\kappa_{IMP}}} - 1\right)^2 IMP_t + \frac{\gamma_{EXP}}{2}\frac{S_t P_{X,t}}{P_t}\left(\frac{\Pi_t^{EXP}}{\left(\Pi_{t-1}^*\right)^{\kappa_{EXP}}\left(\overline{\Pi}^*\right)^{1-\kappa_{EXP}}} - 1\right)^2 EXP_t$$
$$+\frac{P_t^I}{P_t}\left[\gamma_{u_1^K}\left(u_t^K - 1\right) + \frac{\gamma_{u_2^K}}{2}\left(u_t^K - 1\right)^2\right] K_t$$

41 Interest Rate Rule

$$\frac{R_t}{\overline{R}} = \left(\frac{R_{t-1}}{\overline{R}}\right)^{\iota_r}\left[\left(\frac{\Pi_t}{\overline{\Pi}}\right)^{\iota_\pi}\left(\frac{Y_t}{Y_{t-1}}\right)^{\iota_y}\left(\frac{S_t}{\overline{S}}\right)^{\iota_s}\right]^{1-\iota_r} u_t^R$$

42 Imports Demand

$$IMP_t = \alpha_{IMP}\left(\frac{P_{M,t}}{P_{C,t}}\right)^{-\sigma_{IMP}}(C_t + I_t + G_t + I_t^G)$$

43 Exports Demand

$$EXP_t = \alpha_{EXP}\left(\frac{P_{X,t}}{P_{C,t}^*}\right)^{-\sigma_{EXP}} WD_t$$

44 Import Price Inflation

$$(1-\theta_{IMP})\frac{P_{M,t}}{P_t}IMP_t - \gamma_{IMP}\left(\frac{\Pi_t^{IMP}}{\Pi_{t-1}^{\kappa_{IMP}}\overline{\Pi}^{1-\kappa_{IMP}}} - 1\right) IMP_t \frac{\Pi_t^{IMP}}{\Pi_{t-1}^{\kappa_{IMP}}\overline{\Pi}^{1-\kappa_{IMP}}} + \frac{S_t P_t^*}{P_t}\theta_{IMP} IMP_t +$$
$$+\beta\gamma_{IMP} E_t \frac{\lambda_{t+1}^R}{\lambda_t^R}\left(\frac{\Pi_{t+1}^{IMP}}{\Pi_t^{\kappa_{IMP}}\overline{\Pi}^{1-\kappa_{IMP}}} - 1\right) IMP_{t+1}\frac{\Pi_{t+1}^{IMP}}{\Pi_t^{\kappa_{IMP}}\overline{\Pi}^{1-\kappa_{IMP}}} = 0$$

45 Export Price Inflation

$$(1-\theta_{EXP})\frac{S_t P_{X,t}}{P_t}EXP_t - \gamma_{EXP}\left(\frac{\Pi_t^{EXP}}{\left(\Pi_{t-1}^*\right)^{\kappa_{EXP}}\left(\overline{\Pi}^*\right)^{1-\kappa_{EXP}}} - 1\right) EXP_t \frac{\Pi_t^{EXP}}{\left(\Pi_{t-1}^*\right)^{\kappa_{EXP}}\left(\overline{\Pi}^*\right)^{1-\kappa_{EXP}}} + \theta_{EXP} EXP_t +$$
$$+\beta E_t \frac{\lambda_{t+1}^R}{\lambda_t^R}\gamma_{EXP}\left(\frac{\Pi_{t+1}^{EXP}}{(\Pi_t^*)^{\kappa_{EXP}}\left(\overline{\Pi}^*\right)^{1-\kappa_{EXP}}} - 1\right) EXP_{t+1}\frac{\Pi_{t+1}^{EXP}}{(\Pi_t^*)^{\kappa_{EXP}}\left(\overline{\Pi}^*\right)^{1-\kappa_{EXP}}} = 0$$

46 Domestic Consumption Price Index

$$P_{C,t} \equiv \left[(1-\alpha_{IMP})P_t^{1-\sigma_{IMP}} + \alpha_{IMP} P_{M,t}^{1-\sigma_{IMP}}\right]^{\frac{1}{1-\sigma_{IMP}}}$$

47 Euler Equation Related to Foreign Assets

$$S_t\lambda_t^R = \beta E_t \lambda_{t+1}^R \frac{R_t^* + \rho_t^F}{\Pi_{t+1}} S_{t+1}$$

48 Foreign Assets Net Position in Real Terms

$BR_t^F = \frac{R_{t-1}^* + \rho_{t-1}^F}{\Pi_t} \frac{S_t}{S_{t-1}} BR_{t-1}^F + \frac{S_t P_{X,t}}{P_t} EXP_t - \frac{P_{M,t}}{P_t} IMP_t$

49 Risk Premium

$\rho_t^F = -\varphi^F (e^{BR_t^F - BR^F} - 1)$

50 CPI Inflation

$\Pi_t^C = \frac{P_{C,t}}{P_{C,t-1}}$

51 Investment Goods Price Level

$P_{I,t} = P_{C,t}$

52 Investment Goods Inflation

$P_{I,t} = \Pi_t^I P_{I,t-1}$

53 Imported Good Price Level

$P_{M,t} = \Pi_t^{IMP} P_{M,t-1}$

54 Domestic Final Good Price Level

$P_t = \Pi_t P_{t-1}$

55 Foreign Final Good Price Level

$P_t^* = \Pi_t^* P_{t-1}^*$

56 Foreign Consumption Price Index

$P_{C,t}^* = \Pi_t^{C^*} P_{C,t-1}^*$

57 Export Price

$P_{X,t} = \Pi_t^{EXP} P_{X,t-1}$

Table1a: Parametrization

Parameter	Description	Value
β	Discount factor	0.99
δ_K	Depreciation rate of K	0.025
δ_{KG}	Depreciation rate of KG	0.025
α_L	Production function parameter, LL and LH workers	0.35
α_N	Production function parameter, NS and NA workers	0.35
α_G	Production function parameter, public capital	0
α_{IMP}	Share of foreign goods in total consumption	0.26
α_{EXP}	Share of foreign goods in total consumption for the rest of the world	0.26
h_{C^R}	Habit parameter, Ricardian households	0.7
$h_{C^{NR}}$	Habit parameter, non-Ricardian households	0.3
θ_Y	Elasticity of substitution between domestic intermediate goods	5
θ_{EXP}	Elasticity of substitution between exported intermediate goods	5
θ_{IMP}	Elasticity of substitution between imported intermediate goods	5
σ_{IMP}	Elasticity of substitution between domestic and foreign intermediate varieties	1.1
κ_P	Price backward indexation	1
κ_W	Wage backward indexation	1
Π	Steady-state inflation	1
ι_r	Taylor rule parameter, interest	0.8
ι_π	Taylor rule parameter, inflation	1.7
ι_Y	Taylor rule parameter, output	0.125
ι_s	Taylor rule parameter, exchange rate	0.00

Table 1b: Parametrization

Parameter	Description	Value
s_{L_H}	Share of skilled employees	0.11
s_{N_S}	Share of self-employed	0.21
s_{N_A}	Share of atypical workers	0.26
s_{N_R}	Share of non Ricardian households	0.26
σ_L	Elasticity of substitution, skilled and unskilled employees	1.4
σ_N	Elasticity of substitution, atypical and self-employed workers	1.4
σ_{L_H}	Elasticity of substitution, skilled employees	2.65
σ_{L_L}	Elasticity of substitution, unskilled employees	2.65
σ_{N_s}	Elasticity of substitution, self-employed workers	2.65
v_{L_H}	Preference parameter, skilled employees	8.01
v_{L_L}	Preference parameter, unskilled employees	8.36
v_{N_A}	Preference parameter, atypical workers	12.76
v_{N_s}	Preference parameter, self-employed workers	8.00
τ^C	Tax rate of consumption	0.17
τ^K	Tax rate on physical capital	0.33
τ^{L_L}	Average tax rate on unskilled employees	0.24
$\tau_h^{W^{L_L}}$	Social contributions on unskilled employees	0.09
$\tau_f^{W^{L_L}}$	Contributions levied on firms, unskilled employees	0.33
τ^{L_H}	Average tax rate on skilled employees	0.27
$\tau_h^{W^{L_H}}$	Social contributions on skilled employees	0.09
$\tau_f^{W^{L_H}}$	Contributions levied on firms, skilled employees	0.33
τ^{N_S}	Average tax rate on self-employed	0.26
$\tau_h^{W_{N_s}}$	Social contributions on self-employed	0.09
$\tau_f^{W_{N_s}}$	Contributions levied on firms, self-employed	0.00
τ^{N_A}	Average tax rate on atypical workers	0.24
$\tau_h^{W_{N_A}}$	Social contributions on atypical workers	0.09
$\tau_f^{W_{N_A}}$	Contributions levied on firms, atypical workers	0.27

Table 2: Permanent Exogenous Productivity Improvement (1pp)

Years	1	2	3	4	5	10	20	100
Output	0.14	0.16	0.16	0.16	0.16	0.16	0.16	0.18
Consumption	0.11	0.17	0.18	0.18	0.18	0.18	0.18	0.19
Consumption - Ricardian households	0.14	0.21	0.21	0.21	0.21	0.21	0.22	0.23
Consumption - non Ricardian households	-0.02	0.01	0.02	0.02	0.03	0.03	0.03	0.03
Investments	0.08	0.06	0.06	0.06	0.07	0.08	0.10	0.14
Labor	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01
Labor - unskilled employees	0.00	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02
Labor - skilled employees	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.02	-0.02
Labor - self-employed workers	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
Labor - atypical workers	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.03
Real wages	0.13	0.16	0.17	0.17	0.17	0.17	0.18	0.19
Real wages - unskilled employees	0.13	0.16	0.18	0.19	0.19	0.18	0.19	0.20
Real wages - skilled employees	0.11	0.13	0.17	0.19	0.20	0.19	0.19	0.20
Real wages - self-employed workers	0.16	0.18	0.18	0.18	0.18	0.18	0.18	0.20
Real wages - atypical workers	0.05	0.10	0.12	0.13	0.14	0.14	0.15	0.16
Terms of trade	-0.17	-0.13	-0.12	-0.12	-0.12	-0.12	-0.13	-0.15
Exports	0.19	0.14	0.13	0.13	0.13	0.14	0.15	0.16
Imports	-0.06	0.01	0.02	0.02	0.02	0.02	0.02	0.01
Net foreign assets (% output)	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.00
Public debt (% output)	-0.09	-0.20	-0.20	-0.20	-0.20	-0.20	-0.21	-0.22

Note: All variables in percentage deviations from the initial steady state, except foreign assets and public debt to output ratios expressed as percentage-point deviations.

Table 3: Markup Reduction in the Product Market (-10pp)

Years	1	2	3	4	5	10	20	100
Output	1.28	1.77	2.00	2.12	2.22	2.52	2.93	3.80
Consumption	0.26	0.71	0.99	1.14	1.23	1.50	1.84	2.63
Consumption - Ricardian households	0.11	0.50	0.76	0.90	1.00	1.29	1.70	2.62
Consumption - non Ricardian households	0.99	1.75	2.14	2.32	2.41	2.50	2.54	2.63
Investments	2.95	3.37	3.62	3.83	4.02	4.87	6.17	9.06
Labor	0.53	1.00	1.21	1.30	1.36	1.43	1.44	1.41
Labor - unskilled employees	0.44	0.94	1.22	1.37	1.44	1.48	1.45	1.38
Labor - skilled employees	0.17	0.41	0.61	0.76	0.90	1.26	1.42	1.38
Labor- self-employed workers	0.93	1.50	1.57	1.54	1.51	1.47	1.44	1.38
Labor - atypical workers	0.47	0.91	1.11	1.21	1.26	1.34	1.41	1.56
Real wages	2.06	4.26	5.40	5.98	6.30	6.89	7.37	8.31
Real wages - unskilled employees	1.38	3.20	4.53	5.44	6.02	6.92	7.38	8.36
Real wages - skilled employees	0.78	1.80	2.67	3.44	4.08	6.01	7.26	8.36
Real wages - self-employed workers	2.40	4.99	6.10	6.48	6.61	6.91	7.36	8.33
Real wages - atypical workers	2.60	4.75	5.80	6.31	6.57	7.00	7.38	8.19
Terms of trade	-0.36	-0.98	-1.19	-1.31	-1.40	-1.74	-2.20	-3.11
Exports	0.41	1.09	1.33	1.46	1.57	1.95	2.48	3.54
Imports	0.30	0.12	0.15	0.17	0.18	0.18	0.19	0.31
Net foreign assets (% output)	-0.05	-0.07	-0.08	-0.09	-0.11	-0.16	-0.19	-0.02
Public debt (% output)	-1.38	-1.96	-2.46	-2.73	-2.90	-3.31	-3.79	-4.77

Note: All variables in percentage deviations from the initial steady state, except foreign assets and public debt to output ratios expressed as percentage-point deviations.

Table 4: Markup Reductions in the Labor Markets (-10pp)

Years	1	2	3	4	5	10	20	100
Output	0.26	0.54	0.69	0.78	0.83	0.91	0.96	1.04
Consumption	0.32	0.64	0.80	0.89	0.94	1.02	1.06	1.15
Consumption - Ricardian households	0.38	0.77	0.97	1.07	1.13	1.22	1.27	1.38
Consumption - non Ricardian households	0.00	-0.03	-0.03	-0.03	-0.02	0.00	0.00	0.01
Investments	0.04	0.17	0.23	0.28	0.31	0.40	0.53	0.80
Labor	0.22	0.50	0.66	0.76	0.82	0.91	0.93	0.93
Labor - unskilled employees	0.22	0.54	0.76	0.91	1.01	1.11	1.11	1.10
Labor - skilled employees	0.10	0.25	0.38	0.50	0.60	0.91	1.08	1.10
Labor - self-employed workers	0.45	0.91	1.09	1.14	1.14	1.13	1.13	1.12
Labor - atypical workers	0.01	0.03	0.05	0.06	0.07	0.09	0.10	0.11
Real wages	-0.92	-1.13	-0.90	-0.66	-0.50	-0.21	-0.13	-0.03
Real wages - unskilled employees	-1.09	-1.65	-1.53	-1.23	-0.94	-0.39	-0.32	-0.22
Real wages - skilled employees	-1.03	-1.92	-2.21	-2.20	-2.04	-1.10	-0.43	-0.22
Real wages - self-employed workers	-1.16	-1.20	-0.78	-0.52	-0.40	-0.30	-0.25	-0.15
Real wages - atypical workers	0.06	0.16	0.24	0.31	0.35	0.44	0.49	0.56
Terms of trade	-0.08	-0.39	-0.54	-0.62	-0.66	-0.74	-0.79	-0.88
Exports	0.09	0.43	0.59	0.68	0.73	0.82	0.88	0.97
Imports	0.13	0.09	0.08	0.07	0.07	0.06	0.07	0.09
Net foreign assets (% output)	-0.02	-0.04	-0.05	-0.06	-0.06	-0.06	-0.05	0.00
Public debt (% output)	-0.24	-0.46	-0.71	-0.87	-0.97	-1.13	-1.19	-1.30

Note: All variables in percentage deviations from the initial steady state, except foreign assets and public debt to output ratios expressed as percentage-point deviations.

Table 5: Markup Reductions in the Labor Markets - Unskilled Employees (-10pp)

Years	1	2	3	4	5	10	20	100
Output	0.09	0.20	0.29	0.36	0.39	0.45	0.47	0.51
Consumption	0.14	0.27	0.35	0.41	0.44	0.50	0.52	0.56
Consumption - Ricardian households	0.16	0.32	0.42	0.48	0.52	0.59	0.61	0.66
Consumption - non Ricardian households	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.08
Investments	0.00	0.05	0.09	0.12	0.14	0.20	0.26	0.39
Labor	0.10	0.25	0.36	0.43	0.48	0.53	0.53	0.52
Labor - unskilled employees	0.24	0.56	0.80	0.96	1.06	1.19	1.19	1.18
Labor - skilled employees	-0.01	-0.03	-0.05	-0.07	-0.08	-0.13	-0.16	-0.17
Labor - self-employed workers	-0.02	-0.04	-0.05	-0.05	-0.05	-0.05	-0.06	-0.06
Labor - atypical workers	0.01	0.03	0.05	0.06	0.07	0.08	0.08	0.09
Real wages	-0.45	-0.67	-0.63	-0.51	-0.39	-0.15	-0.12	-0.08
Real wages - unskilled employees	-1.30	-2.02	-1.98	-1.71	-1.43	-0.87	-0.81	-0.76
Real wages - skilled employees	0.08	0.21	0.26	0.29	0.31	0.25	0.17	0.20
Real wages - self-employed workers	0.13	0.27	0.35	0.40	0.44	0.50	0.52	0.57
Real wages - atypical workers	0.07	0.16	0.23	0.29	0.33	0.40	0.42	0.46
Terms of trade	0.00	-0.13	-0.22	-0.28	-0.32	-0.37	-0.39	-0.43
Exports	0.00	0.14	0.24	0.31	0.35	0.41	0.43	0.48
Imports	0.09	0.07	0.05	0.03	0.03	0.02	0.03	0.04
Net foreign assets (% output)	-0.01	-0.03	-0.04	-0.05	-0.05	-0.04	-0.03	0.00
Public debt (% output)	-0.10	-0.15	-0.27	-0.37	-0.45	-0.56	-0.59	-0.64

Note: All variables in percentage deviations from the initial steady state, except foreign assets and public debt to output ratios expressed as percentage-point deviations.

Table 6: Markup Reductions in the Labor Markets - Skilled Employees (-10pp)

Years	1	2	3	4	5	10	20	100
Output	0.01	0.01	0.02	0.03	0.04	0.06	0.07	0.08
Consumption	0.01	0.02	0.03	0.04	0.04	0.06	0.07	0.09
Consumption - Ricardian households	0.01	0.02	0.04	0.04	0.05	0.07	0.09	0.10
Consumption - non Ricardian households	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Investments	-0.01	0.00	0.00	0.00	0.01	0.02	0.03	0.06
Labor	0.01	0.03	0.05	0.07	0.08	0.13	0.15	0.15
Labor - unskilled employees	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.03
Labor - skilled employees	0.11	0.29	0.45	0.59	0.71	1.09	1.30	1.33
Labor - self-employed workers	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01
Labor - atypical workers	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Real wages	-0.09	-0.15	-0.18	-0.19	-0.19	-0.14	-0.10	-0.08
Real wages - unskilled employees	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.03
Real wages - skilled employees	-1.31	-2.47	-2.90	-2.96	-2.84	-1.84	-1.07	-0.93
Real wages - self-employed workers	0.00	0.02	0.03	0.03	0.04	0.06	0.08	0.09
Real wages - atypical workers	0.01	0.01	0.02	0.03	0.03	0.05	0.06	0.07
Terms of trade	0.03	0.00	-0.01	-0.02	-0.02	-0.05	-0.06	-0.07
Exports	-0.03	0.00	0.01	0.02	0.03	0.05	0.07	0.07
Imports	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.01
Net foreign assets (% output)	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	0.00
Public debt (% output)	-0.03	0.00	-0.01	-0.02	-0.03	-0.06	-0.09	-0.10

Note: All variables in percentage deviations from the initial steady state, except foreign assets and public debt to output ratios expressed as percentage-point deviations.

Table 7: Markup Reductions in the Labor Markets - Self-Employed Workers (-10pp)

Years	1	2	3	4	5	10	20	100
Output	0.16	0.32	0.38	0.39	0.39	0.40	0.41	0.45
Consumption	0.17	0.34	0.42	0.44	0.45	0.45	0.46	0.49
Consumption - Ricardian households	0.21	0.42	0.52	0.55	0.55	0.56	0.57	0.61
Consumption - non Ricardian households	-0.03	-0.07	-0.08	-0.09	-0.09	-0.09	-0.09	-0.08
Investments	0.04	0.12	0.14	0.15	0.16	0.19	0.24	0.35
Labor	0.11	0.22	0.26	0.26	0.26	0.25	0.25	0.25
Labor - unskilled employees	-0.01	-0.02	-0.03	-0.04	-0.04	-0.05	-0.06	-0.06
Labor - skilled employees	0.00	-0.01	-0.01	-0.02	-0.02	-0.04	-0.05	-0.06
Labor - self-employed workers	0.47	0.96	1.15	1.19	1.20	1.20	1.19	1.19
Labor - atypical workers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Real wages	-0.40	-0.31	-0.09	0.03	0.07	0.08	0.09	0.13
Real wages - unskilled employees	0.20	0.36	0.44	0.47	0.48	0.46	0.48	0.51
Real wages - skilled employees	0.19	0.33	0.42	0.48	0.50	0.50	0.48	0.51
Real wages - self-employed workers	-1.29	-1.49	-1.15	-0.95	-0.88	-0.85	-0.84	-0.80
Real wages - atypical workers	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	0.01	0.04
Terms of trade	-0.09	-0.27	-0.31	-0.32	-0.32	-0.32	-0.34	-0.38
Exports	0.10	0.29	0.34	0.35	0.35	0.36	0.38	0.42
Imports	0.03	0.00	0.02	0.03	0.03	0.04	0.03	0.04
Net foreign assets (% output)	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public debt (% output)	-0.12	-0.30	-0.43	-0.49	-0.50	-0.50	-0.52	-0.56

Note: All variables in percentage deviations from the initial steady state, except foreign assets and public debt to output ratios expressed as percentage-point deviations.

Table 8: Overhead Labor Reduction (-10%)

Years	1	2	3	4	5	10	20	100
Output	0.96	0.97	0.92	0.89	0.88	0.88	0.91	0.98
Consumption	0.71	1.07	1.07	1.04	1.03	1.02	1.03	1.08
Consumption - Ricardian households	0.93	1.36	1.36	1.33	1.32	1.31	1.32	1.38
Consumption - non Ricardian households	-0.40	-0.35	-0.36	-0.38	-0.38	-0.40	-0.40	-0.39
Investments	0.51	0.39	0.37	0.38	0.39	0.44	0.54	0.76
Labor	-0.13	-0.24	-0.31	-0.35	-0.37	-0.40	-0.41	-0.41
Labor - unskilled employees	-0.11	-0.24	-0.33	-0.39	-0.43	-0.47	-0.47	-0.47
Labor - skilled employees	-0.04	-0.11	-0.17	-0.22	-0.26	-0.39	-0.46	-0.47
Labor - self-employed workers	-0.27	-0.43	-0.51	-0.52	-0.52	-0.51	-0.51	-0.51
Labor - atypical workers	-0.04	-0.07	-0.09	-0.10	-0.10	-0.10	-0.10	-0.09
Real wages	0.44	0.15	0.04	-0.07	-0.13	-0.22	-0.20	-0.14
Real wages - unskilled employees	0.62	0.43	0.37	0.23	0.11	-0.08	-0.06	0.01
Real wages - skilled employees	0.63	0.58	0.69	0.67	0.59	0.22	-0.02	0.01
Real wages - self-employed workers	0.54	0.12	-0.07	-0.18	-0.22	-0.23	-0.20	-0.13
Real wages - atypical workers	-0.27	-0.34	-0.43	-0.48	-0.50	-0.52	-0.49	-0.43
Terms of trade	-1.13	-0.80	-0.71	-0.68	-0.68	-0.69	-0.74	-0.83
Exports	1.26	0.89	0.78	0.76	0.75	0.77	0.82	0.92
Imports	-0.43	0.04	0.12	0.12	0.12	0.11	0.10	0.08
Net foreign assets (% output)	0.10	0.15	0.15	0.15	0.14	0.10	0.05	0.00
Public debt (% output)	-0.58	-1.21	-1.16	-1.10	-1.07	-1.04	-1.07	-1.16

Note: All variables in percentage deviations from the initial steady state, except foreign assets and public debt to output ratios expressed as percentage-point deviations.

Table 9: Tax Shift from Labor to Consumption (1% of Output)

Years	1	2	3	4	5	10	20	100
Output	0.05	0.14	0.18	0.20	0.21	0.23	0.24	0.26
Consumption	-0.02	0.15	0.21	0.24	0.25	0.27	0.27	0.29
Consumption - Ricardian households	0.21	0.34	0.38	0.40	0.41	0.42	0.43	0.45
Consumption - non Ricardian households	-1.18	-0.77	-0.62	-0.56	-0.53	-0.50	-0.50	-0.50
Investments	0.06	0.06	0.07	0.08	0.09	0.11	0.14	0.20
Labor	0.07	0.16	0.20	0.23	0.24	0.26	0.27	0.27
Labor - unskilled employees	0.04	0.10	0.14	0.17	0.19	0.21	0.21	0.21
Labor - skilled employees	0.02	0.05	0.08	0.11	0.13	0.20	0.24	0.24
Labor - self-employed workers	0.08	0.17	0.21	0.22	0.22	0.22	0.22	0.22
Labor - atypical workers	0.18	0.35	0.42	0.46	0.47	0.49	0.49	0.49
Real wages	-0.36	-0.32	-0.25	-0.19	-0.15	-0.09	-0.07	-0.05
Real wages - unskilled employees	-0.14	-0.26	-0.24	-0.18	-0.13	-0.02	0.00	0.02
Real wages - skilled employees	-0.17	-0.37	-0.43	-0.43	-0.40	-0.20	-0.05	0.00
Real wages - self-employed workers	-0.18	-0.23	-0.16	-0.10	-0.08	-0.06	-0.05	-0.02
Real wages - atypical workers	-1.89	-0.91	-0.56	-0.39	-0.32	-0.25	-0.24	-0.22
Terms of trade	-0.12	-0.12	-0.14	-0.15	-0.16	-0.18	-0.20	-0.22
Exports	0.13	0.13	0.15	0.17	0.18	0.20	0.22	0.25
Imports	-0.10	0.00	0.02	0.03	0.03	0.03	0.02	0.02
Net foreign assets (% output)	0.02	0.03	0.03	0.03	0.03	0.02	0.01	0.00
Public debt (% output)	-0.01	-0.16	-0.23	-0.26	-0.29	-0.32	-0.34	-0.36

Note: All variables in percentage deviations from the initial steady state, except foreign assets and public debt to output ratios expressed as percentage-point deviations.

Figure 1: Response to a Temporary Productivity Improvement (1%)

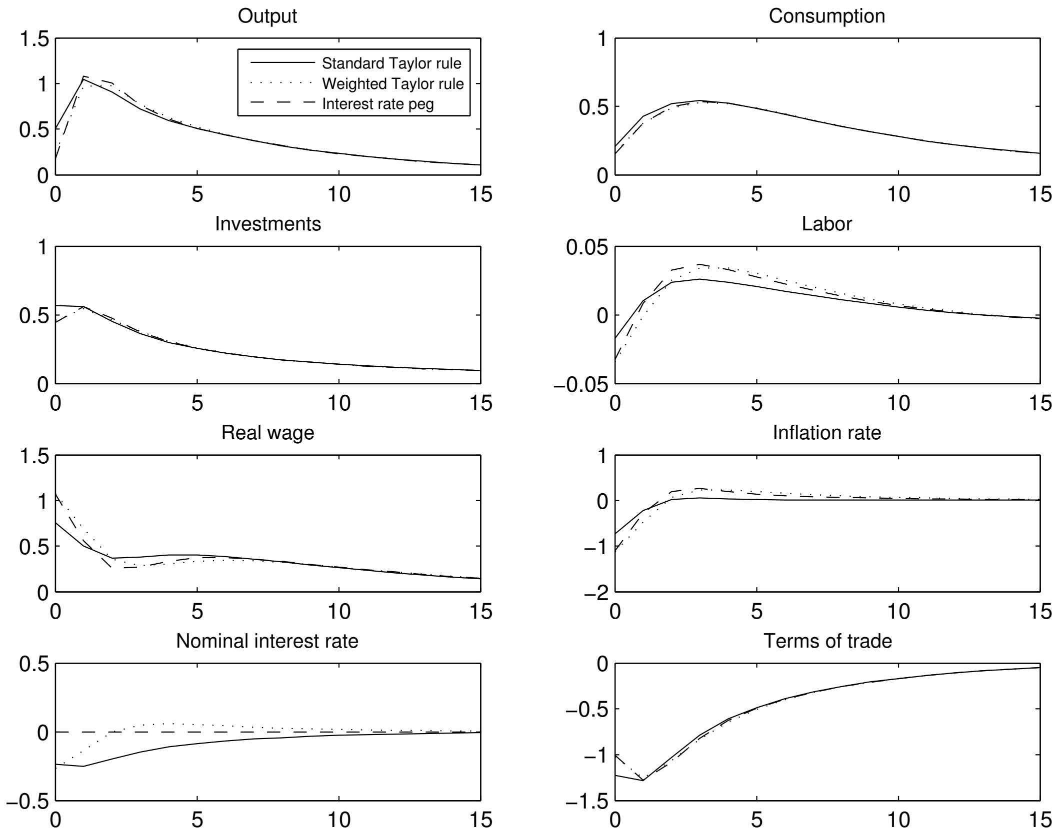

Figure 2: Response to a Temporary Increase in Public Consumption (1%)

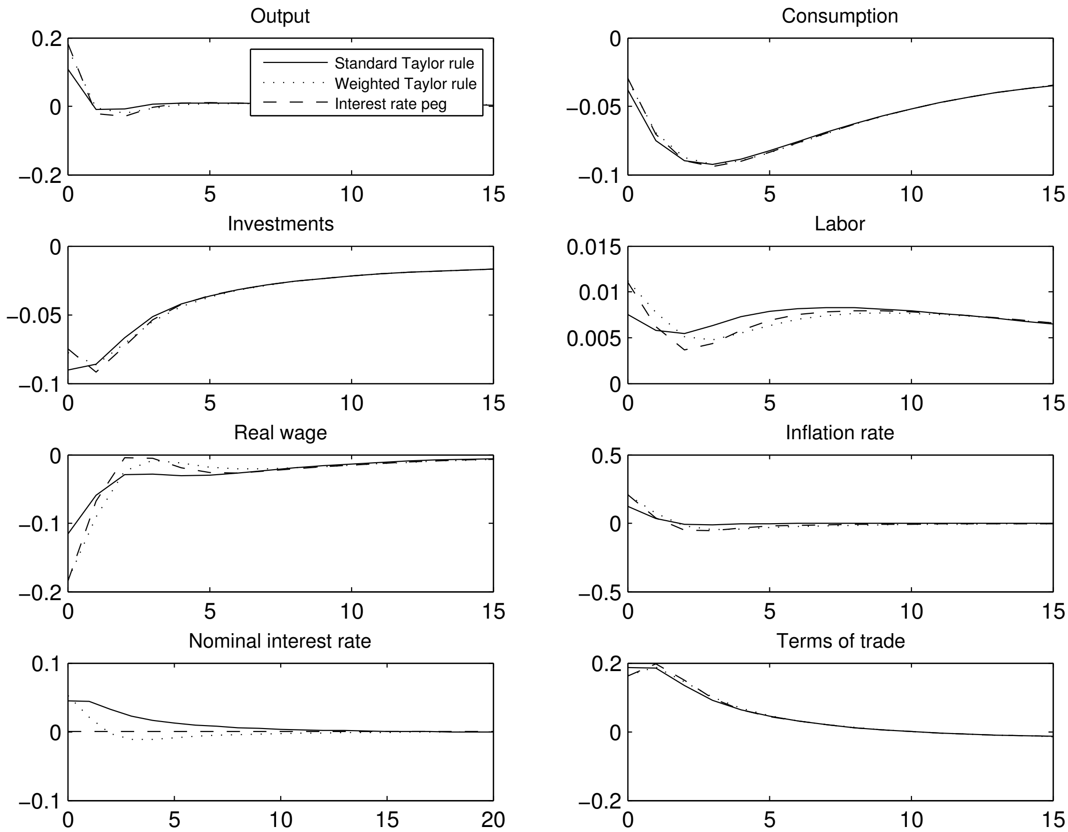

Figure 3: Response to a Monetary Policy Shock (1%)