Increasing the Value Added Tax in Spain*

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Summary: In this article we quantify the consequences of increasing the Value Added Tax Rates in Spain. We compare the results that we obtain in two model economies: a standard representative agent neoclassical growth model economy, and a heterogeneous household overlapping generations model economy. Our heterogeneous household model economy predicts that when the government uses the consumption tax to raise revenues, each 1 percentage point increase in government revenues reduces output per capita at factor prices by 0.52 percentage points and total hours worked by 0.75 percentage points. In spite of this, the Spanish official statistics will not show the reduction in output per capita because they report the values of gross domestic product at market prices. Our model economy also predicts that most of the increase in the tax burden will be paid by the poor, the old, the high school dropouts, the disabled, and the retirees. These findings lead us to conclude that increasing the value added tax rate in Spain will probably have a non-trivial depressing effect on economic activity, that it will be clearly regressive, and that it will probably come too early.

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1 Introduction

The use of large scale heterogeneous agents models with incomplete markets to evaluate the aggregate and distributional consequences of tax reforms is now a standard tool of policy analysis in economics. Several authors build on the model structure of Aiyagari (1994) or Huggett (1996) to carry counterfactual exercises in order to compare allocations under different tax regimes.[1] In these model economies, the existence of idiosyncratic shocks to labor earnings (or to hourly wages) and the absence of market to trade securities contingent on these shocks, imply that the aggregation result by Gorman (1953) does not hold and hence there is no representative agent characterization of the economy. In other words, the the decision rules are not linear in wealth and hence, in order to predict next period aggregate allocations and prices, individuals need to know who owns the wealth. This poses a big computational burden because the whole distribution of households over the individual state variables becomes part of the aggregate state of the economy. However, Krusell and Smith (1998) show that for reasonably calibrated economies, *approximate aggregation* holds: by only knowing average wealth today one can predict tomorrow's aggregate allocations extremely well.[2] The intuition is that by saving and borrowing with a risk free bond, households can self-insure themselves very well, almost as well as with state-contingent securities. Only those individuals with little wealth show curvature in their decision rules, but these individuals weight very little for computing aggregate allocations.

An interesting question that arises then is whether the response to changes in policy parameters by a heterogeneous agents economy with incomplete markets is going to be very different from the response by a representative agent economy. In particular, heterogeneous agents models are carefully calibrated to reproduce the income and wealth distribution of the economy, as well as the demographic structure of the population. The reason is that changes in the tax parameters change incentives to work and save differently for people at different points of the income and wealth distribution, as well as for people at different stages of the life-cycle. When doing this type of exercises, the presumption is that the effects of tax changes in consumption and hours of work are not linear, and hence the average response over the whole population is different from the response of an average individual.

To answer this question, in this article we use two versions of the neoclassical growth model to evaluate the aggregate and distributional consequences of a value added tax reform. The first model economy is the standard deterministic version of the representative agent neoclassical growth model, which is very similar to the model economy described in Conesa and Kehoe (2009). The second model economy is an overlapping generations model populated by heterogeneous households, which resembles the model economy described in Díaz-Giménez and Díaz-Saavedra (2009). In this model economy the households differ exogenously in their place of birth, in their age, and in their education. And they differ endogenously in their employment status, in their wealth, and in their pension entitlements. They receive a stochastic endowment of efficiency labor

[1] For instance, Ventura (1999) and Díaz-Giménez and Pijoan-Mas (2006) evaluate the impact of replacing the current income tax by a flat tax scheme in the US economy; González-Torrabadella and Pijoan-Mas (2006) perform a similar exercise for the Spanish economy; Domeij and Heathcote (2004) look at the welfare effects of eliminating the capital income tax; Conesa and Krueger (2006) and Conesa, Kitao, and Krueger (2009) characterize the optimal shape of the income tax function.

[2] The approximate aggregation result by Krusell and Smith (1998) turned out to be quite robust through different variations of the basic model. For instance, Pijoan-Mas (2007) show that the result persists when we add habit formation to household preferences; Storesletten, Telmer, and Yaron (2007) show that the result persist when we replace the infinitely-lived households by an overlapping generations model.

units each period. And they face a disability risk and a survival risk. They understand the link between the payroll taxes that they pay and the public pensions that they receive. And they decide how much to consume and to work, and when to retire from the labor force. We want to compare the aggregate allocations that arise in the two model economies, and we use the heterogeneous agents economy to study the distributional consequences of the reform.

The tax reform we focus on is the tax hike in the value added tax rates announced by the Spanish government in the Fall of 2009. Specifically, in September 2009, the Spanish government announced that in July 1st 2010, the general tax of the Value Added Tax (VAT) will increase from 16 percent to 18 percent, that the reduced VAT tax rate will increase from 7 to 8 percent, and that the super-reduced tax rate, which applies to basic food, will be kept at 4 percent. Since our model period is one year, we consider the tax announcement to happen at the beginning of 2009 and the tax increase to happen at the beginning of 2010. Since we have only one consumption good in our models, we do our tax reform as if the unique VAT that applies to all goods increases in 2 percentage points.

We calibrate our two model economies so that they both replicate the same main Spanish macroeconomic aggregates and ratios for the year 2008 and so that they have the same elasticity of substitution between consumption and leisure. In addition, the heterogeneous agents economy is calibrated to replicate the demographic and educational structure of the Spanish population, as well as the distribution of labor earnings. We then simulate our two economies from 2009 onwards. In our simulations we assume that total factor productivity remains constant at its 2008 value, and that the law of motion of the population is consistent with the Spanish demographic and educational transitions. In the representative agent economy the change in the age and educational composition of the population is translated into a change in the average efficiency units of labor of the representative household. We assume a zero growth rate of the total factor productivity because, according to Conesa and Kehoe (2009), the average growth rate of Spanish total factor productivity has been close to zero during the past 15 years, and we do not expect it to depart from this average in the near future. We model the Spanish demographic and educational transitions because Díaz-Giménez and Díaz-Saavedra (2006) make a compelling argument that play large roles in the immediate future of the Spanish economy.

In our benchmark model economies we keep tax rates and government expenditures constant at their 2008 values, and we use lump-sum transfers to satisfy the government budgets. In our reformed model economies we increase the consumption tax rate two percentage points in 2010 and we keep all other tax rates and government expenditures unchanged. The reform is announced in 2009. In that year we keep all tax rates and government expenditures at their 2008 values. And, once again, we use lump-sum transfers to satisfy the government budgets.

Our main finding is that the changes in aggregate allocations and total government revenues predicted by the two model economies are very similar.

In particular, we find the following: First, in the heterogeneous household model economy the tax increase announcement in 2009 results in a 0.71 percent reduction of the gross domestic product per capita at factor prices that year, and the actual tax increase results in reductions of about between 0.9 and 1.0 percentage points per year between 2010 and 2016.[3] The representative agent model predicts a fall in the gross domestic product per capita at factor prices in 2009 of 0.66 percent, and between 0.8 and 0.9 percent in the next year.

Second, according to the heterogenous agents model, total tax revenues increase by 1.71% in 2010, but they decline by 0.76% in 2009. According to the representative agent model, total tax revenues increase by 1.73% in 2010, but they decline by 0.58% in 2009. The reason for the small increase in tax revenues in 2010 is that the tax revenues from capital and labor income fall. For the next years, the heterogeneous agents model predicts that the increase in tax revenues will be declining, from 1.70 in 2011 to 1.66 in 2016. Instead, the representative agent model predicts that the increase in tax revenues will be increasing, from 1.74 in 2011 to 1.89 in 2016. The differences are small, albeit the trends are diverging.

Third, the burden of the tax increase falls relatively more on the retirees (as opposed to working age households), households with little wealth and households with little labor income relative to their education group. The main reasons is that for these groups of households the value added tax represents a very big share of their overall tax liabilities. This confirms the regressive nature of indirect taxation.

Hence, we conclude that when the focus is only to predict changes in aggregate allocations and government revenues, a properly calibrated representative agent model can do a very good job. Of course, the representative agent model is silent about the distributional impact of the reform and, given that the utility functions are concave, will give downward biased measurements of the welfare changes.

2 The Representative Agent Model Economy (REP)

Our representative agent model economy is a standard neoclassical growth model economy populated by a representative household, a representative firm, and a government.

2.1 The Representative Household

The representative household solves the following decision problem:

$$\max E\left\{\sum_{t=0}^{\infty}\beta^t\left[\log C_t+\alpha\log(100N_t-H_t)\right]\right\} \tag{1}$$

subject to

$$(1+\tau_{ct})C_t+A_{t+1}=(1-\tau_{lt})w_t\epsilon_t H_t+(1-\tau_{kt})r_t A_t+Z_t \tag{2}$$

where C_t denotes aggregate consumption; N_t denotes the working age population; H_t denotes total hours worked; ϵ_t denotes average efficiency units of labor; A_t denotes total assets owned by households; Z_t denotes transfers; τ_{ct}, τ_{kt}, and τ_{lt} denote the tax rates on consumption, capital, and labor; w_t and r_t denote the wage and the interest rate; and A_0 is given. We use variable ϵ_t to account for the Spanish educational transition.

[3] In spite of this, the official statistics will not show these reductions because they report the values of gross domestic product at market prices, which includes indirect taxes.

2.2 The Representatitve Firm

There is a stand-in firm with the following Cobb-Douglas production function

$$Y_t = K_{t+1}^{\theta} \left(B_t L_t\right)^{1-\theta} \tag{3}$$

where K_t is the stock of capital, L_t the total number of efficiency units of labor hired by the firm and B_t denotes an exogenous labor-augmenting productivity factor whose law of motion is $B_{t+1} = (1+\gamma_t) B_t$, with $B_0 > 0$. Note that there are two potential sources of productivity growth: B_t and ϵ_t. Although these two variables play the same role in our model economy, we keep them separate for measurement reasons. We also assume that the capital stock depreciates geometrically at a constant rate, $0 < \delta < 1$.

The solution to the firms maximization problem implies that

$$r_t = \theta \left(\frac{K_{t+1}}{B_t L_t}\right)^{\theta-1} - \delta \tag{4}$$

and that

$$w_t = (1-\theta) \left(\frac{K_{t+1}}{B_t L_t}\right)^{\theta} \tag{5}$$

2.3 The Government

The government's budget constraint is

$$G_t + Z_t = \tau_{ct} C_t + \tau_{lt} w_t \epsilon_t H_t + \tau_{kt} r_t A_t \tag{6}$$

where G_t is government consumption.

2.4 Equilibrium

Given the initial values of A_0 and K_0, an equilibrium for this model economy is an allocation $\{C_t$, A_{t+1}, H_t, Y_t, I_t, K_{t+1}, $L_t\}_{t=1}^{\infty}$, a government policy $\{G_t, Z_t, \tau_{ct}, \tau_{lt}, \tau_{kt}\}_{t=1}^{\infty}$, and a price vector $\{r_t, w_t\}_{t=1}^{\infty}$ such that,

- The representative household solves its optimization problem described in expressions (1) and (2) taking the price vector, and the government policy as given.
- The representative firm solves its optimization problem, and its optimal decisions satisfy expressions (4) and (5).
- The government satisfies its budget constraint described in expression (6).
- All markets clear

$$K_{t+1} = A_{t+1} \tag{7}$$

$$L_t = \epsilon_t H_t \tag{8}$$

$$Y_t = C_t + G_t + I_t \tag{9}$$

where $I_t = K_{t+1} - (1-\delta) K_t$ is aggregate gross investment.

3 The Heterogeneous Household Model Economy (HET)

Our heterogeneous household model economy is an overlapping generations model economy populated by heterogeneous households, a representative firm, and a government.

3.1 Households

We assume that our model economy is inhabited by continuum of heterogeneous households, which we normalize each period so that its measure is always equal to one. The households differ in their place of birth, $\ell \in \mathcal{L}$; in their education, $h \in H$; in their age, $j \in J$; in their employment status, $e \in \mathcal{E}$; in their assets, $a \in A$; and in their pension claims, $b \in B \cup B^d$. Sets $\mathcal{L}$, H, J, $\mathcal{E}$, A, B, and B^d are all finite sets and we describe below. We use $\mu_{\ell,h,j,e,a,b,t}$ to denote the measure of households of type (ℓ, h, j, e, a, b) at period t. For convenience, whenever we integrate the measure of households over some dimension, we drop the corresponding subscript.

Place of birth. Households can be either immigrants, and then $\ell = i$, or native, and then $\ell = n$. Consequently $\mathcal{L} = \{i, n\}$. We assume that a measure μ_{it} of immigrants enters the economy at the beginning of each period, and that this measure is exogenous. We assume that immigrants enter the economy with zero assets and that their age and educational distributions are those reported by the *Instituto Nacional de Estadística.*[4]

Education. We abstract from the education decision. Instead we assume that the education of both natives and immigrants is determined forever when they enter the economy. We consider three educational levels. Therefore, $H = \{1, 2, 3\}$. Level $h = 1$ denotes that the household has dropped out of high school.[5] Level $h = 2$ denotes that the household has completed high school but has not completed college. And level $h = 3$ denotes that the household has completed college.

Age. Both native households and the youngest immigrants enter the economy when they are 20 years old and they live up to a maximum of 100 years. Consequently, $J = \{20, 21, \ldots, 100\}$.

Population dynamics. Each period both immigrants and natives face an age-dependent and time-varying conditional probability of surviving from age j to age $j+1$, which we denote by ψ_{jt}. They also face an age-dependent and time-varying probability of bearing offspring, which we denote by f_{jt}. We assume that the survival probabilities and fertility rates of immigrants and natives are the same because independent data for these two population groups are not readily available. Finally, we treat the offspring of immigrants as natives.

These assumptions imply that at the beginning of every period there is a measure $1 + n_t$ of households in our economy. Variable n_t denotes the population growth rate, which we compute as follows:

$$n_t = \mu_{it} + \sum_J \left[\psi_{j,t-1} + f_{j,t-1}\right] \mu_{j,t-1} - 1. \tag{10}$$

[4] See Díaz-Giménez and Díaz-Saavedra (2005) for the details.

[5] In this group we include every household that has not completed the compulsory education. Due to the changes in the Spanish educational laws, we define the compulsory studies to be either the *Estudios Secundarios Obligatorios*, the *Graduado Escolar*, the *Certificado Escolar*, or the *Bachiller Elemental.*

We normalize the measures of households each period so that the law of motion of μ_{jt} becomes

$$\mu_{20,t+1} = \frac{1}{(1+n_{t+1})}\left[\mu_{i,20,t+1} + \sum_{J} f_{jt}\mu_{jt}\right] \tag{11}$$

and

$$\mu_{j,t+1} = \frac{1}{(1+n_{t+1})}\left[\mu_{i,j,t+1} + \psi_{j-1,t}\mu_{j-1,t}\right] \tag{12}$$

for each $j > 20$.

Employment status. Households in our economy are either workers, disabled households, or retirees. We denote workers by ω, disabled households by d and retirees by ρ. Consequently, $\mathcal{E} = \{\omega, d, \rho\}$. The households enter the economy as workers. They face a disability shock each period of their working lives, and they can retire after they reach age R_0. A distinguishing feature of our model economy is that workers and disabled households can choose to become retirees when the reach the first retirement age.

Workers. Workers receive an endowment of efficiency labor units every period. This endowment has two components: a deterministic component, which we denote by ϵ_{hj}, and a stochastic idiosyncratic component, which we denote by s. We use the deterministic component to characterize the life-cycle profile of earnings for different educational groups and we describe it in Section 4.2.1 below. We use the stochastic component to generate earnings and wealth inequality within the age cohorts. We assume that s is independent and identically distributed across households and that it follows a first order, finite state Markov chain with conditional transition probabilities given by $\Gamma[s' \mid s] = \Pr\{s_{t+1} = s' \mid s_t = s\}$, where $s, s' \in \omega = \{s_1, s_1, \ldots, s_n\}$.

Disabled households. We assume that a worker of education level h and age j faces a probability φ_{hj} of becoming disabled from age $j+1$ onwards. The workers receive the disability shock at the end of the period, once they have made all their labor and consumption decisions. When a worker becomes disabled, it exits the labor market and it receives no further endowments of efficiency labor units, but she is entitled to receive a disability pension. When a disabled worker reaches the first retirement age, R_0, she decides whether to keep its disability pension, or to exchange it for a retirement pension.

Retirees. Workers of age R_0 or older observe their endowment of efficiency labor units and they decide whether remain in the labor force that period, or whether to retire and start collecting their retirement pensions. Naturally, retirees receive no endowments of efficiency labor units.

Assets. We assume that the households in our model economy cannot borrow. Since leisure is an argument of their utility function, this borrowing constraint can be interpreted as a solvency constraint that prevents the households from going bankrupt in every state of the world. These restrictions give the households a precautionary motive to save. They do so accumulating real assets, which we denote by a_t, and which take the form of either productive capital or government debt. For computational reasons we restrict the asset holdings to belong to the discrete set $\mathcal{A} = \{a_0, a_1, \ldots, a_n\}$. We choose $n = 49$, and assume that $a_0 = 0$, that $a_{49} = 155$, and that the spacing between points in set $\mathcal{A}$ is increasing.[6]

Pension claims. For computational reasons we restrict the retirement pension claims to belong to the discrete set $B = \{b_{0t}, b_{1t}, \ldots, b_{mt}\}$, where b_{0t} is the minimum retirement pension and and b_{mt} is the maximum retirement pension. We also restrict the disability pension claims to belong to the discrete set $B^d = \{b^d_{0t}, b^d_{1t}, \ldots, b^d_{mt}\}$. We choose $m = 9$, and we assume that the points in sets B and B^d are equally spaced.

Market Arrangements. We assume that there are no insurance markets for the stochastic component of the endowment shock. This is a key feature of this class of model worlds. When insurance markets are allowed to operate, every household of the same birthplace, age, and education level is alike, and the income and wealth distributions in our model economy become much more disperse.

The Households' Decision Problem. We assume that the households in our model economy have identical preferences, and that they solve the following decision problem:

$$\max E \left\{ \sum_{j=20}^{100} \beta^{j-20} \, \psi_{jt} \, \left[\log c_{hjt} + \alpha \log(1 - l_{hjt}) \right] \right\} \tag{13}$$

subject to

$$c_{hjt} + a_{hjt+1} + \tau_{hjt} = (1 + r_t) \, a_{hjt} + y_{hjt} \, \mathcal{I}_{\omega t} + b_{dt} \, \mathcal{I}_{dt} + b_t \, \mathcal{I}_{\rho t} + z_t \tag{14}$$

to

$$\tau_{hjt} = \tau_{ct} \, c_{hjt} + \tau_{kt} \, r_t \, a_{hjt} + \tau_{lt} [y_{hjt} - \tau_{st}(y_{hjt}) \, \mathcal{I}_{jt \leq R_1}] + \tau_{st}(y_{hjt}) \, \mathcal{I}_{jt \leq R_1} \tag{15}$$

and to

$$y_{hjt} = w_t \, \epsilon_{hj} \, s_t \, l_{hjt} \tag{16}$$

where $a_{hjt} \in \mathcal{A}$, $b_t \in B$, $b_{dt} \in B^d$ for all t, and a_{hj0} is given. Parameter $\beta > 0$ denotes the time discount factor, c_{hjt} denotes consumption, l_{hjt} denotes labor, a_{hjt+1} denotes the end-of-period assets, τ_{hjt} denotes total tax payments, r_t is the net rate of return on capital, y_{hjt} is labor income, b_t is the retirement pension, b^d_t is the disability pension, z_t denotes the non-pension transfers, and the functions $\mathcal{I}_{\omega t}$, $\mathcal{I}_{dt}$, $\mathcal{I}_{\rho t}$, indicate whether the household is a worker, a disabled household, or a retiree during period t.[7] In Expression (15) τ_{ct} denotes the consumption tax, τ_{kt} the capital income tax, τ_{lt} the labor income tax, $\tau_{st}(y_{hjt})$ the payroll tax function, and indicator function $\mathcal{I}_{jt \leq R_1}$ indicates whether the worker is R_1 years old or younger, where R_1 denotes the normal retirement age.[8] Finally, in Expression (16), w_t denotes the wage rate per efficiency labor unit.

[6] In overlapping generation models with finite lives and no altruism there is no need to impose an upper bound for set $\mathcal{A}$ since households who reach the maximum age will optimally consume all their assets. İmrohoroğlu, İmrohoroğlu, and Joines (1995) make a similar point.

[7] Recall that workers decide whether to retire after they observe their endowment shock s.

[8] In 2002 the Spanish public pension system was amended and workers older than R_1 years were exempted from paying payroll taxes. We use indicator function $\mathcal{I}_{jt \leq R_1}$ to replicate this feature of the Spanish pension system in our model economy.

3.2 The Representative Firm

The representative firms in our two types of model economy are identical. Consequently, the representative firm in our heterogeneous household model economy behaves competitively in the product and factor markets, it maximizes profits, and is production function and the first order conditions of its decision problem are described in Expressions (3), (4), and (5). Labor productivity grows for the same two reasons in both types of model economies: because we assume that there is an exogenous labor augmenting productivity factor, and because the productivity workers increases as they become more educated.

3.3 The Government

The government taxes labor income, capital income, and consumption, and it issues one-year real government debt. It uses its revenues to consume and to make transfers to households, and it runs a pay-as-you-go pension system. In this model economy the government budget constraint is

$$G_t + Z_t = T_{ct} + T_{kt} + T_{lt} + E_t \tag{17}$$

where G_t denotes government consumption, Z_t transfers other than pensions, T_{ct}, T_{kt}, and T_{lt}, denote the revenues collected by the consumption tax, the capital income tax, and the labor income tax, and E_t denotes the unintentional bequests of deceased households.

To buffer the model economy from the large distortions that would result from the large public pension deficits brought about by the demographic and educational transitions, we assume that pension surpluses and deficits are accumulated in a Pension Reserve Fund which evolves according to

$$F_{t+1} = (1 + r^*)F_t + T_{st} - P_t \tag{18}$$

where F_t denotes the value of the fund at the beginning of period t, r^* is the exogenous rate of return of the fund's assets, T_{st} denotes the revenues collected by the payroll tax, and P_t denotes total pension payments.

3.4 Definition of equilibrium

Let $\ell \in \mathcal{L}$, $h \in H$, $j \in J$, $e \in \mathcal{E}$, $a \in \mathcal{A}$, and $b \in B \cup B^d$, and let $\mu_{\ell,h,j,e,a,b,t}$ be a probability measure defined on $\Re = \mathcal{L} \times J \times H \times \mathcal{E} \times \mathcal{A} \times B$.[9] Then, given initial conditions μ_0, B_0, E_0, F_0, and K_0, a competitive equilibrium for this economy is a government policy, $\{G_t, P_t, Z_t, T_{ct}, T_{kt}, T_{lt}, T_{st}, E_{t+1}, F_{t+1}\}_{t=0}^{\infty}$, a household policy, $\{c_t(h,j,e,a,b), l_t(h,j,e,a,b), a_{t+1}(h,j,e,a,b)\}_{t=0}^{\infty}$, a sequence of measures, $\{\mu_t\}_{t=0}^{\infty}$, a vector of factor prices, $\{r_t, w_t\}_{t=0}^{\infty}$, a vector of macroeconomic aggregates, $\{Y_t, K_{t+1}, L_t, I_t\}_{t=0}^{\infty}$, a function, Q, and a number, r^*, such that:

(i) Factor inputs, pension payments, transfers, tax revenues, and accidental bequests are obtained aggre-

[9]Recall that, for convenience, whenever we integrate the measure of households over some dimension, we drop the corresponding subscript. We also drop the first subscript whenever there are no differences between immigrants and natives.

gating over the model economy households as follows:

$$K_{t+1} = \int a_{hjt+1} d\mu_t \tag{19}$$

$$L_t = \int \epsilon_{hj} s_t l_{hjt} d\mu_t \tag{20}$$

$$P_t = \int (b_t + b_{dt}) d\mu_t \tag{21}$$

$$Z_t = \int z_t d\mu_t \tag{22}$$

$$T_{ct} = \int \tau_{ct} c_{hjt} d\mu_t \tag{23}$$

$$T_{kt} = \int \tau_{kt} r_t a_{hjt} d\mu_t \tag{24}$$

$$T_{lt} = \int \tau_{lt} \left[y_{hjt} - \tau_{st}(y_{hjt})\, I_{j \leq R_1} \right] d\mu_t \tag{25}$$

$$T_{st} = \int \tau_{st}(y_{hjt})\, I_{j \leq R_1}\, d\mu_t \tag{26}$$

$$E_{t+1} = \int (1 - \psi_{jt})(1 + r_{t+1}) a_{hjt+1} d\mu_t \tag{27}$$

where $y_{hjt} = w_t\, \epsilon_{hj}\, s_t\, l_{hjt}$ and all the integrals are defined over the state space $\Re$.

(ii) Given the initial conditions and the government policy, the household policy solves the households' decision problem defined in Expressions (13), (14), (15) and (16).

(iii) Given the initial conditions the macroeconomic aggregates satisfy Expressions (3) and (30), and the factor prices are the factor marginal productivities defined in Expressions (4) and (5).

(iv) The government policy and r^* satisfy the government budget constraint described in Expression (17), and the law of motion of the pension system fund described in Expression (18).

(v) The goods market clears:

$$\int_{\Re} c_{hjt} d\mu_t + K_{t+1} + G_t + (T_{st} - P_t) = F(K_t, B_t L_t) + (1 - \delta) K_t. \tag{28}$$

The last term of the left-hand side of this expression is not standard. It states that fthe pension system surpluses are invested in the pension fund and that the pension deficits are financed using the proceeds of the fund or borrowing from abroad when the fund is exhausted. This term would show up as net exports in the standard national income and product accounts. Note that if we define net investment I_t as,

$$I_t = F(K_t, B_t L_t) - \int_{\Re} c_{hjt} d\mu_t - G_t - (T_{st} - P_t) \tag{29}$$

equation (28) implies the law of motion of aggregate capital:

$$K_{t+1} = (1 - \delta) K_t + I_t \tag{30}$$

(vi) The law of motion for μ_t is:

$$\mu_{t+1} = \int_{\Re} Q_t d\mu_t. \tag{31}$$

Describing function Q formally is complicated because it specifies the transitions of the measure of households along its six dimensions: place of birth, education level, age, employment status, assets holdings, and pension entitlements. An informal description of this function is the following: since the flows of immigrants are exogenous to the model economy, the evolution of μ_{it} is also exogenous. The evolution of μ_{ht} is implied by the educational shares of immigrants and native new-entrants, both of which are exogenous. The evolution of μ_{jt} is described in Expressions (10), (11) and (12). The evolution of μ_{et} is governed by the conditional transition probability matrix, Γ, the probability of becoming disabled, and the optimal decision to retire. We assume that both immigrants and natives enter the economy as able workers, that they do not own any assets, and that they draw the stochastic component of their initial endowment of efficiency labor units from the invariant distribution of s. The evolution of μ_{at} is determined by the optimal savings decision. Finally, the evolution of μ_{bt} is determined by the rules of the Spanish public pension system as described in Section 4.2.2.

4 Calibration

To calibrate our model economies we target the 2008 Spanish macroeconomic aggregates and ratios that we report in Table 1.

Table 1: Macroeconomic Aggregates and Ratios in 2008 (%)

	C^*/Y^*	I/Y^*	G/Y^*	K/Y^*	Y_k/Y	h	T_c/C	T_l^*/Y_l	T_k/Y_k	T_l/Y^*	T_s/Y^*	P/Y^*
Spain	54.0	27.9	18.1	3.19[a]	35.3	21.1	17.0	32.6	49.7	6.8	12.4	11.7

*Variables C^* and Y^* denote private consumption and GDP at market prices; variable Y denotes GDP at factor cost; and variable T_l^* is the sum of the labor income share of the Personal Income Tax collections and the payroll tax collections.
[a]The target for K/Y is in model units and not in percentage terms.

Our targets for the expenditure shares reported in the first block of Table 1 are the values of the Spanish shares for 2008. To compute those shares, our target for C^* is the value of Spanish private consumption; our target for I is the value of Spanish gross capital formation; and our target for G is the value of the Spanish public consumption, all three for 2008 and measured at current market prices. And our definition for Y^* is $Y^* = C^* + G + I$. Our values for K and h are the values for the Spanish capital stock and hours for 2008.[10] Our targets for Y_l and Y_k are the nominal GDP shares of labor income and of all income other than labor income for Spain in 2008. Our target for T_c is the indirect tax collections reported for 2008 by the Spanish National Income and Product Accounts; our target for T_k is the sum of the capital income share of the Personal Income tax collections and the Corporate Income tax collections; our target for T_l is the labor income share of the Personal Income Tax collections; and our target for T_s is the Payroll Tax collections

[10]For details on the way these series were computed, see Conesa and Kehoe (2009).

paid by both workers and firms. All our tax statistics are reported by the OECD.[11] Finally, our definition for $T_l^* = T_l + T_s$ and our target for P is the value reported by the Spanish Social Security Administration.

4.1 The Representative Agent Model Economy

To simulate our representative agent model economy, we start in 1970 taking the initial value of the capital stock K_0 from the data and we choose its parameters so that in 2008 the model economy replicates the Spanish macroeconomic aggregates and ratios that we report in Table 1. Specifically, our target for h determines the value of the leisure share in the utility function, $\alpha = 2.97$; our target for K/Y^* determines our value for the time discount factor, $\beta = 0.997$; our target for I/Y determines the value of the capital depreciation rate, $\delta = 0.074$; and our target for Y_K/Y determines the capital share parameter of the utility function, $\theta = 0.352$. Finally the value for the G/Y^* ratio in our model economy is determined directly by the Spanish target, and so are the average tax rates, τ_c, τ_k, and τ_{l^*}.

From 2009 onwards we proceed as follows: we take the series for the population and for the endowment of efficiency labor units, N_t and ϵ_t, from the projections of the demographic and educational transitions reported in Díaz-Giménez and Díaz-Saavedra (2006); we assume that total factor productivity B_t remains constant at its 2008 value; we keep all tax rates and government expenditures constant at their 2008 values; and we determine the value of the sequence of government transfers residually to satisfy the government budget constraint.

4.2 The Heterogenous Household Model Economy

We calibrate our heterogeneous household model economy so that it replicates as closely as possible the institutional details, the macroeconomic aggregates, and the distributional features of the Spanish economy in 2008. The age and the educational transitions are completely independent from the economic decisions, and they are determined by the survival probabilities, the fertility rates, and the flows of immigrants all of which are exogenous. We have discussed these transitions in detail in Díaz-Giménez and Díaz-Saavedra (2006), and for the sake of brevity we do not discuss them here. The initial conditions that we need to simulate our model economy from 2008 onwards are B_0, F_0, and the initial distribution of households, μ_0, which implies the initial value for the capital stock, K_0.[12]

4.2.1 The Endowment of Efficiency Labor Units

To model the deterministic component of the endowment of efficiency labor units that represents the life cycle profile of earnings, we use quadratic functions of the following form:

$$\epsilon_{hj} = a_{1h} + a_{2h}j - a_{3h}j^2 \tag{32}$$

This functional form captures the concavity of the workers' productivity profiles over their life-cycle in a very parsimonious way. We represent these functions in Panel A of Figure 1.

[11] Again, see Conesa and Kehoe (2009) for the details.
[12] Naturally, the value of μ_0 is determined by the age and educational transitions.

We assume that the process on the stochastic component of the endowment takes three values. Therefore, $s \in \{s_1, s_2, s_3\}$. We make this assumption because it turns our that three states are sufficient to account for the Lorenz curves of the Spanish distributions of income and labor earnings in sufficient detail, and because we want to keep this process as parsimonious as possible.

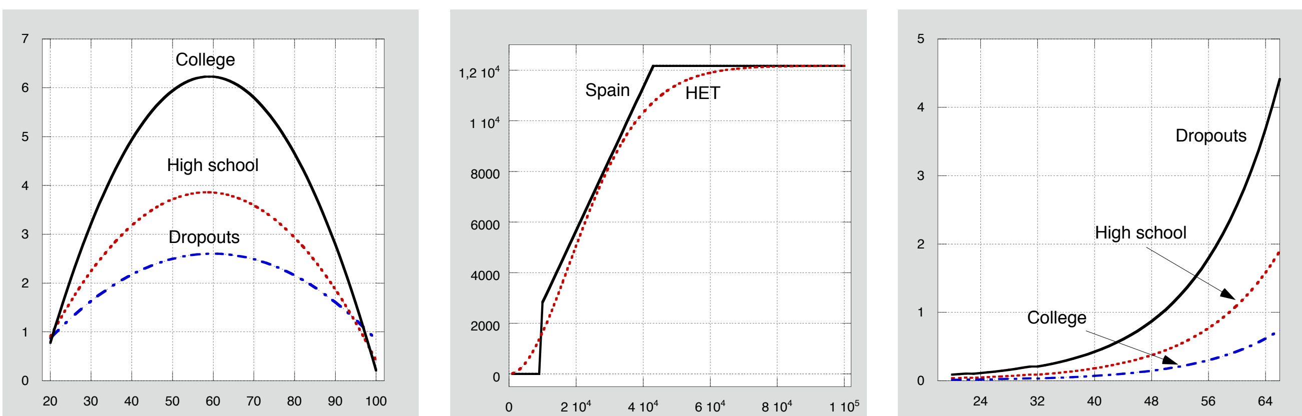
4.2.2 The Spanish Pension System

Payroll taxes. The Spanish pension system is financed with a payroll tax on gross labor earnings. The payroll tax is capped and it has a tax-exempt minimum. The payroll tax in our model economy is described by function, $\tau_s(y_{hjt})$. Our choice for this function is the following:

$$\tau_{st}(y_{hjt}) = a_4\bar{y}_t - \left[a_4\bar{y}_t \left(1 + \frac{a_5 y_{hjt}}{a_4\bar{y}_t} \right)^{-y_{hjt}/a_4\bar{y}_t} \right] \tag{33}$$

Parameter a_4 is the cap of the payroll tax and $\bar{y}_t$ is per capita income at period t. This functional form allows us to replicate the Spanish payroll tax cap, but it does not allow us to replicate the tax exempt minimum. In Panel B of Figure 1 we represent the payroll tax function for our chosen values of a_4 and a_5 for 2008.

Figure 1: The Endowment of Efficiency Labor Units, the Payroll Tax, and the Disability Risk



Panel A: The Efficiency Labor Units

Panel B: The Payroll Tax Funcion

Panel C: The Disability Risk

Retirement pensions. Pensions in our model economy are computed according to the following formula, which replicates the main features of Spanish pensions.

$$b_t = \frac{1}{N_b}\phi(1.02)^q(1-\lambda_j)\sum_{t=j-N_b}^{j-1}\min\{a_6\bar{y}_t, y_{hjt}\} \tag{34}$$

where parameter N_b denotes the number of consecutive years immediately before retirement that are used to compute the pension. Parameter $0<\phi<1$ denotes the pension system replacement rate. Variable q denotes the number of years that the worker remains in the labor force after reaching the normal retirement age.[13]

[13]This late retirement premium was introduced in the 2002 Amendment of the Spanish Public Pension System.

Function $0 \leq \lambda_j < 1$ is the early retirement penalty. And $a_6 \bar{y}_t$ is the maximum covered earnings. Following the Spanish system, we compute our model economy pensions upon retirement and we index them to the rate of growth of output.

To replicate the Spanish minimum and maximum retirement pensions, we also require that

$$b_{0t} < b_t < b_{mt} \tag{35}$$

where b_{0t} denotes the minimum pension and b_{mt} denotes the maximum pension. These limits vary with time because the Spanish minimum and maximum retirement pensions are adjusted discretionally to keep up with the growth of output.

The Spanish *Régimen General de la Seguridad Social* establishes that the penalties for early retirement are a linear function of the retirement age. To replicate this rule, our choice for the early retirement penalty function is the following

$$\lambda_j = \begin{cases} a_7 - a_8(j - R_0) & \text{if } j < R_1 \\ 0 & \text{if } j \geq R_1 \end{cases} \tag{36}$$

Finally, the Spanish pension replacement rate is a function of the number of years of contributions. In our model economy we abstract from this feature because it requires an additional state variable.

Disability pensions. We model disability pensions explicitly for three reasons: because they represent a large share of all Spanish pensions (10.8 percent of all pensions in 2008), because most of the data on retirement and pensions lump together old age and disability, and because in many cases disability pensions are used as an alternative route to early retirement.[14] In accordance with the current Spanish rules, we assume that there is a minimum disability pension which coincides with the minimum retirement pension. And that the disability pensions are 75 percent of the households' retirement claims. Formally, our disability pensions are computed as follows:

$$b_{dt} = \max\{b_{0t}, 0.75 b_t\}. \tag{37}$$

We assume that after a disabled household reaches the first retirement age, R_0, it can change its disability pension for a retirement pension paying the early retirement penalty if applicable.[15]

Disability risk. To determine the values of the probabilities of becoming disabled, φ_{hj}, we proceed in two stages. First we model the aggregate probability of becoming disabled. We denote by p_j, and we assume that it is determined by the following function:

$$p_j = a_9 e^{(a_{10} \times j)} \tag{38}$$

We make this choice because, according to the *Boletín de Estadísticas Laborales* (2007), the number of disabled people in Spain increases more than proportionally with age. Once p_j is determined, to compute

[14] See Boldrin and Jiménez-Martín (2003) for an elaboration of this argument.

[15] The Spanish rules contemplate a special reduction of the first retirement age for disabled households. The reduction is proportional to the number of years of contributions. We have not included this feature in our model economy for computational reasons.

the values of φ_{hj}, we solve the following system of equations:

$$\begin{cases} p_j \mu_{j,2007} & = & \sum_h \varphi_{hj} \mu_{hj,2007} \\ \varphi_{2j} & = & a_{11} \varphi_{1j} \\ \varphi_{3j} & = & a_{12} \varphi_{1j} \end{cases} \tag{39}$$

We make these choices because in Spain the number of disabled households differs significantly across educational types. Consequently, to characterize the disability probabilities, we must choose the values of 4 parameters. We represent our chosen values for φ_{hj} in Panel C of Figure 1.[16]

4.2.3 Parameters

When all is told, to characterize our model economy fully, we must choose the values of a total of 50 parameters. Of these 50 parameters, 2 describe the household preferences, 3 the production technology, 21 the endowment of efficiency labor units process, 5 the government policy, 12 the pension system rules, 4 the disability risk, and the remaining 3 parameters describe the initial conditions. We report our choices for these 50 parameters in Tables 2, 3, and 4.

4.2.4 Targets

To find the values of the 50 model economy parameters, we need 50 equations or calibration targets which we describe below.

Macroeconomic aggregates and ratios. From the macroeconomic aggregates and ratios that we report in the first two blocks of Table 1 we use the values of I/Y^*, K/Y^*, Y_k/Y, and h to give give us four independent conditions or targets.

Pension system targets. To identify the payroll tax function described in Expression (33), we must choose the values of parameters a_4 and a_5. In 2008 in Spain, the payroll tax rate paid by households was 28.3 percent and it was levied only on the first 43,037 euros of annual gross labor income. Hence, the maximum contribution was 12,179 euros which correspond to 51 percent of the Spanish per capita GDP. To replicate this number, in our model economy we choose $a_4 = 0.51$. The value for a_5, is implied by our requirement that the revenues collected by the payroll tax in the model economy match the 12.4 percent of output collected in the Spanish economy.

Our choice for the number of years used to compute the retirement pensions in our model economy is $N_b = 15$. This is because the Spanish *Régimen General de la Seguridad Social* considers the last 15 years of contributions prior to retirement to compute the pension. We assume that the minimum, and maximum pensions and the maximum covered earnings are directly proportional to per capita income. Our targets for the coefficients are $b_{0t} = 0.19$, $b_{mt} = 1.39$, and $a_6 = 1.80$. These numbers correspond to their Spanish values for 2008 for workers included in the *Régimen General*.[17]

[16] The data on disability can be found at www.mtas.es/estadisticas.

[17] Specifically, in 2008 the minimum retirement pension in Spain was 4,616 euros, the maximum pension was 33,383 euros, the maximum covered earnings were 43,037 euros, and per capita GDP was 23,874 euros.

We choose our first and normal retirement ages to be $R_0 = 60$ and $R_1 = 65$. In Spain the first retirement age was 60 until 2002. This rule was changed in 2002 when the first retirement age was delayed to 61, with some exceptions. We choose $R_0 = 60$ because in 2003 a large number of workers were still retiring at that age.[18] For the early retirement penalty parameters, we choose $a_7 = 0.4$, and $a_8 = 0.08$. This is because we have chosen $R_0 = 60$ and because in Spain the penalties for early retirement are 8 percent for every year before age 65. The value of the pension replacement rate, ϕ is implied by the requirement that our model economy replicates the pension payments to output ratio in Spain in 2008 which was 11.7 percent.

Finally, for the rate of return on the pension reserve fund's assets we choose $r^* = 0.02$. We also ran simulations $r^* = 0.01$, $r^* = 0.03$ and $r^* = 0.04$. The only results that vary with r^* are the values of the pension fund. These changes are small and they do not modify the conclusions of this article. The pension system gives us a total of 12 targets.

Government policy targets. Of all the variables included in the government budget described in Expressions (17) and in the law of motion of the pension reserve fund described in Expression (18), we must still target the values of T_{ct}, T_{kt}, T_{lt}, E_t and Z_t. The targets for the tax collections are those reported in the last two blocks of Table 1. Unintentional bequests, E_t, are endogenous and we do not impose any restriction on their value. And we use transfers, Z_t, to satisfy the government budget. Therefore the value of this variable is determined residually. This gives us a total of 5 targets.

The life-cycle profile of earnings targets. We want the deterministic component of the efficiency labor unit profiles of the educational groups in our model economy, ϵ_{hj}, to replicate the profiles reported by the *Instituto Nacional de Estadística* in the *Encuesta de Salarios en la Industria y los Servicios* (2000) for the Spanish economy. In our model economy we use quadratic functions to model these empirical profiles and we use the wage survey data to determine the values of the nine parameters of Expression (32) directly. This gives us 9 additional targets.[19]

The disability risk targets. We want the probability of becoming disabled to approximate the disablility profile reported by the *Boletín de Estadísticas Laborales* (2007) for the Spanish economy. We use the Spanish data to determine the values of parameters a_9 and a_{10} in Expression (38). Further, according to the *Instituto de Mayores y Servicios Sociales*, in 2008 in Spain 62.6 percent of the total number of disabled people aged 25 to 44 years old had not completed high school, 26.9 percent had completed high school, and the remaining 10.5 percent had completed college. We use these shares to determine the values of parameters a_{11} and a_{12} of Equation (39). Specifically, we choose $a_{11} = 0.269/0.626 = 0.4297$ and $a_{12} = 0.105/0.626 = 0.1677$. This gives us 4 targets.

Distributional targets. We target also the three Gini indexes and five points of the Lorenz curves of the Spanish distributions of earnings, income and wealth for 2004. We have taken these statistics from Budría

[18] García Pérez et al. (2008) reports that around 20 percent of age 60 active people chose to collect the retirement pension during 2007.

[19] Since we only have data until age 64, we estimate the quadratic functions for workers in the 20–64 age cohort and we project the resulting functions from age 65 onwards. The year 2000 dataset is the last data sate available on the age-profiles of wages by educational types.

Table 2: Values for 29 of the Model Economy Parameters in 2008

	Parameter	Value
Preferences		
Leisure share	α	3.8195
Time discount factor	β	1.0121
Technology		
Capital depreciation rate	δ	0.0725
Productivity growth rate	γ	0.0000
Labor share	θ	0.3533
Government Policy		
Government consumption	G	0.8218
Government transfers	Z	0.1794
Consumption tax rate	τ_c	0.1698
Capital income tax rate	τ_k	0.4973
Labor income tax rate	τ_l	0.1438
Public Pension System		
Payroll tax cap	a_4	2.3235
Payroll tax rate	a_5	0.2060
Maximum covered earnings	a_6	8.2102
Maximum early retirement penalty	a_7	0.4000
Early retirement penalty per year	a_8	0.0800
Pension replacement rate	ϕ	0.5311
Minimum retirement pension	b_{0t}	0.8804
Maximum retirement pension	b_{mt}	6.3682
Number of years of contributions	N_b	15
First retirement age	R_0	60
Normal retirement age	R_1	65
Rate of return for the pension fund	r^*	0.0200
Disability Risk		
	a_9	0.000449
	a_{10}	0.0924
	a_{11}	0.4291
	a_{12}	0.1677
Initial Conditions		
Initial total factor productivity	A_0	1.0000
Initial capital stock	K_0	14.5504
Initial pension reserve fund	F_0	0.2413

and Díaz-Giménez (2006), and we report them in Table 6. Castañeda, Díaz-Giménez, and Ríos-Rull (2003) argue in favor of this calibration procedure to replicate the inequality reported in the data. This gives us a total of 8 targets.

Initial conditions. Our choice for the initial value of the pension reserve fund is $F_{2008} = 0.0545Y_{2008}$. This number corresponds to the value of the Spanish pension fund at the end of 2008. The initial value of the capital stock implied by the distribution of households in 2008 is $K_{2008} = 14.5504$ which corresponds to a capital output ratio of $(K/Y)_{2008} = 3.19$ which is our targeted value of 3.19. And we choose the initial value of the total factor productivity to be $A_0 = 1$. Initial conditions give us three targets.

Normalization conditions. In our model economy there are four normalization conditions. The transition probability matrix on the stochastic component of the endowment of efficiency labor units process is a Markov matrix and therefore its rows must add up to one. This property imposes three normalization conditions. We also normalize the first realization of this process to be $s(1) = 1$. These normalization conditions give us 4 additional equations.

Adding up. Notice that we have specified a total of 50 equations or targets. Of these 50 targets, 4 are macroeconomic aggregates and ratios, 12 describe the pension system, 5 are government policy targets, 9 the deterministic component of the endowment of efficiency labor units process, 4 the disability risk function, 8 target distributional statistics, 3 are initial conditions, 4 are normalization conditions, and our last target is the value of the growth rate of the labor-augmenting productivity process which we assume to be $\gamma = 0$. The 50 parameters and the 50 targets define a full rank non-linear system of 50 equations in 50 unknowns.

Table 3: The Deterministic Component of the Endowment Process

	$h = 1$	$h = 2$	$h = 3$
$a_{1,h}$	–1.3018	–2.9624	–6.2441
$a_{2,h}$	0.1305	0.2334	0.4227
$a_{3,h}$	0.001091	0.001997	0.003582

4.2.5 Choices

We obtain values of 31 of the model parameters directly either because they are determined uniquely by single targets, or because they are normalization conditions. These parameters are independent of the endogenous variables of the model. The values of 5 of the remaining parameters are implied by our guesses for aggregate capital and labor. To determine the values of the remaining 14 parameters, we solve the system of 14 non-linear equations in 14 unknowns obtained from imposing that the relevant statistics of the model economy should be equal to the corresponding targets. Solutions for these systems are not guaranteed to exist and, when they do exist, they are not guaranteed to be unique.[20] Consequently, we tried many different initial

[20] Actually we solved a smaller system of 13 equations and 13 unknowns because the value of Z is determined residually from the government budget.

values in order to find the best parameterization possible. To solve this system of equations we use a standard non-linear equation solver. Specifically, we use a modification of Powell's hybrid method, implemented in subroutine DNSQ from the SLATEC package. We report the numerical choices for the 50 model economy parameters in Tables 2, 3, and 4.

Table 4: The Stochastic Component of the Endowment Process

		Transition Probabilities			
	Values	$s' = s_1$	$s' = s_2$	$s' = s_3$	$\pi^*(s)^a$
$s = s_1$	1.0000	0.8760	0.1239	0.0000	27.53
$s = s_2$	4.2030	0.0831	0.7225	0.1942	40.91
$s = s_3$	5.8921	0.0003	0.2515	0.7481	31.56

[a] $\pi^*(s)$% denotes the invariant distribution of s.

5 Results: The Calibration Exercise

Table 5: Macroeconomic Aggregates and Ratios in 2008 (%)

	C^*/Y^*	I/Y^*	G/Y^*	K^a/Y^*	Y_K/Y	h	T_l^*/Y_l	T_k/Y_k	T_c/C	T_l/Y^*	T_s/Y^*	P/Y^*
Spain	54.0	27.9	18.1	3.19	35.3	21.1	32.6	49.7	17.0	6.8	12.4	11.7
REP	52.9	27.9	19.2	3.19	35.3	21.1	32.6	49.7	17.0	6.8	12.4	11.7
HET	54.0	27.9	18.1	3.19	35.3	21.4	32.3	49.7	17.0	6.8	12.4	11.7

[*] Variables C^* and Y^* denote private consumption and GDP at market prices; variable Y denotes GDP at factor cost; and variable T_l^* is the sum of the Personal Income Tax collections and the payroll tax collections.
[a] The target for K/Y is in model units and not in percentage terms.

5.1 Macroeconomic Aggregates and Ratios

In Table 5 we report the macroeconomic aggregates and ratios in Spain and in our Benchmark model economies for 2008. We find that both economies replicate the Spanish targets very well. The only missalignment for the Representative agent model is that the share of consumption to output is 1.1 percent lower, at the expense of the share of government spending; the only differences for the Heterogeneous household model are in the amount of hours worked, which are 21.4 in the model economy and 21.1 in Spain, and in the total labor income tax collections ratios, which are 32.3 and 32.6 percent of labor income.

5.2 Other Calibration Targets

Inequality. In Table 6 we report the Gini indexes and selected points of the Lorenz curves of earnings, income and wealth in Spain and in our model economy. The statistics that we report in bold face are our eight calibration targets. The source for the Spanish data is the 2004 *Encuesta Financiera de las Familias Españolas* as reported in Budría and Díaz-Giménez (2006b). The model economy statistics correspond to

Table 6: The Distributions of Earnings, Income and Wealth*

		Bottom Tail			Quintiles					Top Tail		
	Gini	1	1–5	5–10	1st	2nd	3rd	4th	5th	10–5	5–1	1
The Earnings Distributions (%)												
Spain	**0.49**[a]	0.0	0.7	1.2	**5.3**	**10.9**	**16.2**	**23.3**	**44.3**	10.9	11.5	5.6
HET	0.49	0.0	0.0	0.0	0.5	7.9	18.1	23.6	49.9	12.3	14.0	5.1
Δ	0.00	0.0	0.7	1.2	4.8	3.0	–2.1	–0.3	–5.6	–1.4	–2.5	0.5
The Income Distributions (%)												
Spain	**0.42**	0.0	0.7	1.1	5.4	10.7	15.9	23.3	44.6	10.7	11.1	6.4
HET	0.43	0.0	0.3	0.5	3.3	10.0	16.6	23.6	46.4	11.0	13.9	5.6
Δ	–0.01	0.0	0.4	0.6	2.1	0.7	–0.7	–0.3	–1.8	–0.3	–2.8	0.8
The Wealth Distributions (%)												
Spain	**0.57**	–0.1	–0.0	0.0	0.9	6.6	12.5	20.6	59.5	12.5	16.4	13.6
HET	0.62	0.0	0.0	0.0	0.1	3.5	10.9	22.2	63.3	16.7	19.8	6.6
Δ	–0.05	–0.1	0.0	0.0	0.8	3.1	1.6	–1.6	–3.8	4.2	3.4	7.0

*The source for the Spanish data is the 2004 *Encuesta Financiera de las Familias Españolas* as reported in Budría and Díaz-Giménez (2006b). The model economy statistics correspond to 2008.
[a]The statistics in bold face have been targeted in our calibration procedure.

2008. We find that our heterogeneous household model economy replicates reasonably well the Spanish Gini indexes of the earnings and income distributions. When we compare the earnings and income shares of the quintiles we find that the bottom forty percent of both distributions earn larger shares in the model economy than in Spain, and that the top two quintiles of both distributions earn more. The fact that the model economy can account for the Lorenz curve of income reasonably well is particularly remarkable since we have not used any of its points as our calibration targets. We also find that wealth is more concentrated in our model economy than in Spani. This is due to a larger concentration of wealth in the top two quintiles. In spite of this, the largest differences between our heterogeneous household model economy and the Spanish data are in the the top 1 percent of the wealth distribution where wealth is sizably more concentrated in Spain. This disparity was expected because in general, overlapping generations economies fail to account for the large shares of wealth owned by the richest households in the data.[21]

Table 7: Retirement Behavior

	Avg Ret Ages		%Part at 60-64		
	Spain[a]	HET	Spain[b]	HET	Spain[c]
All	62.6	63.3	36.4	52.9	56.6
Dropouts	*n.a.*	63.1	30.5	47.7	49.5
High School	*n.a.*	63.5	40.1	61.2	64.9
College	*n.a.*	66.6	57.1	66.3	66.7

[a]The Spanish data is for both males and females in 2008 (Source: Eurostat).
[b]The Spanish data is the average of the four quarters of 2008 of the *Encuesta de la Población Activa*.
[c]The Spanish data is the average of the four quarters of 2008 of the *Encuesta de la Población Activa*, excluding the unemployed and non-participants who do not collect either retirement or disability pensions.

[21]See Castañeda, Díaz-Giménez, and Ríos-Rull (2003) for an elaboration on this argument.

Retirement Behavior. In the first panel of Table 7 we report the average retirement age in Spain and in our heterogeneous household model economy. We find that the average retirement age in our model economy is 63.3 years, which is 0.7 years more than in the Spanish economy.[22] We also find that the average retirement ages in the model economy are increasing in the number of years of education. This finding was to be expected since the returns to working are increasing in the number of years of education. We do not have the corresponding data for the Spanish economy but we think that this increasing relationship is intuitively plausible.

In the last panel of Table 7 we report the labor participation rates of the households that belong to the 60–64 age cohort. When carrying out this comparison we must keep in mind that there are some fundamental differences between Spain and our model economy. In Spain, working-age people fall into one of five categories: employed, unemployed, retired, disabled, and other non-participants. In our model economy we only have three of these categories: employed, retired, and disabled. These differences account for the large differences between the data in the third and the fifth columns of that table. In the third column we include the participation rates as reported by the *Encuesta de la Población Activa.* In the fifth column we report the participation rate excluding from the non-participants both the unemployed and the non-participants who do not collect retirement or disability pensions. We find that the participation rates in our model economy lie between these two estimates of the Spanish participation rates, and that they come very close to the numbers that we have obtained using our second measure. This finding is particularly encouraging because the participation statistics are not part of our calibration targets. Therefore they can be interpreted as overidentifying restrictions for our model economy.

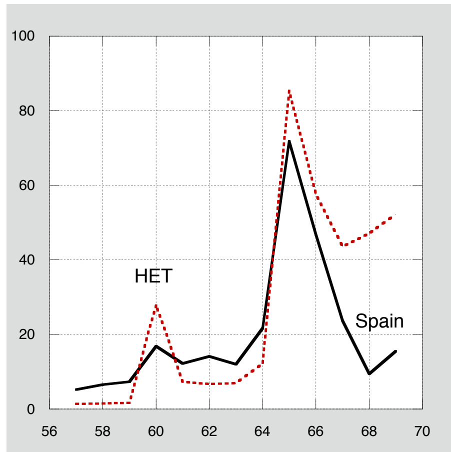
Again we find that the participation rates of the elderly are increasing in education both in our model economy and in the data. Two reasons justify this relationship. First, many dropouts are entitled to minimum pensions only. Consequently, these workers are not affected by the early retirement penalties and they choose to retire as early as possible. And second, even though all the educational types value leisure equally, the foregone labor income, which is the opportunity cost of leisure, is smaller for less educated workers. Consequently, more educated workers tend to participate more than their less educated colleagues.

In Figure 2 we report the probabilities of exiting the labor force due to retirement or disability. Naturally these exit probabilities are conditional on being a worker at the beginning of the period.[23] Two features stand out from this comparison. Qualitatively, our model economy does a fair job in replicating the general shape of the retirement and disability hazards observed in Spain. Quantitatively, more households retire in our model economy both at age 60 (28 percent of the sixty year olds in the model economy and 17 percent in Spain) and at 65 (85 percent of the sixty year olds in the model and 72 percent in Spain). Part of this discrepancy can be due to the fact that to calibrate our model economy we target hours worked per person in the 16–65 age cohort, which are approximately 21 percent. To replicate this low number, households in our model economy must value leisure a lot. If we had targeted the number of hours worked per labor market participant, which was approximately 28 percent according to the *Instituto Nacional de*

[22] The Spanish average retirement age has been computed for both male and female workers, it corresponds to the year 2008 and it is reported in Eurostat. Every number reported in this section for our model economy corresponds to the year 2008.

[23] The Spanish data are reported in Jiménez-Martín (2006) and they correspond to Spanish males in 2003.

Figure 2: Retirement and Disability Hazards (%)



Estadística, the model economy households would have valued leisure less and therefore more of them would have chosen to extend their working-lives beyond the first retirement age. In contrast between ages 61 and 64 the probabilities of retiring are higher in Spain than in the model economy.

6 Results: Increasing the Value Added Tax

To simulate the increase in the value added tax that has been proposed for Spain in our model economies we proceed as follows. Our calibration for the year 2008 gives us the set of state variables for our two model economies in 2009: the initial capital stock K_{2009} for the representative agent model economy and the initial distribution of households, μ_{2009}, and the initial value of the Pension Reserve Fund F_{2009} for the heterogeneous household model economy. Then, in 2009 we modify the tax system rules. We keep all taxes rates and government expenditures constant at their 2008 values, but households learn that from 2010 onwards the consumption tax will be raised two percentage points, while all other tax rates and government expenditures will remain constant at their 2008 values. The sequences $\{N_t, B_t, \epsilon_t\}$ between 2009 and 2050 are kept as in the calibration exercise. We report the results of our policy exercise in Tables 8 and 9 and in Figures 3 and 4. Our two economies predict very similar results in terms of signs. In Table 8 we have boldfaced the results that differ in sign and only output at market prices in 2014, 2015, and 2016 meets that criterion and barely because all the values are very close. We also find that the magnitudes of the changes are larger in the heterogeneous household model economy, but that the differences are not large. In Table 8 we have also boldfaced the results that differ in more than one percentage point and there are only two instances our of 94 possible pairs: investment in 2009, that differs by 2.27 percentage points, and the consumption tax revenues of 2010, that differ by exactly 1.00 percentage points.

6.1 Aggregate Output and Inputs

Our main finding is that this policy exercise implies a non-trivial reduction in output per capita at market prices in 2009, and almost no change in the subsequent years. In particular, both model economies predict a reduction of around 0.57 percentage points for 2009 in output per capita at market prices. However, this result is misleading. Output at market prices grows mechanically due to an increase in the value added tax. If we measure output at factor costs instead, we compute the change in output net of the price increases that result from the increase in the indirect tax collections. In that case, the representative household model economy predicts a reduction of output of 0.66 percent in 2009 and of about 0.85 percent in the following years. The heterogeneous household model economy predicts a 0.71 percent reduction in 2009 and of about 1.0 percent in the following years. Hence, the reform brings about sizable losses in output for the following years, although the standard measure of output per capita at market prices hides these losses.

This reduction in output at factor prices is brought about by the reductions of both the capital and labor inputs. A higher consumption tax rate increases the tax wedge between the marginal rate of substitution between consumption and leisure and its relative price. In particular, with a higher taxation of consumption goods bought in the market, households in the representative household model economy choose to work around 1 percent less, and they devote more time to non-market activities such as home production or leisure. In the heterogeneous household model economy, total hours decrease by 1.2 percent in 2009 and by about 1.3 percent in the following years. The increase in the consumption tax rate also reduces the resources devoted to capital formation. This brings about a gradual decline of the capital stock. In the representative household model economy, the reductions of the capital stock range from 0.27 percent in 2010 to 0.56 percent in 2016. In the heterogeneous household model economy, the reductions range from 0.33 percent to 0.83 percent.

6.2 Aggregate Consumption and Investment

The increase in the consumption tax is announced in 2009, one year before it takes place. As possibly intended by the policy makers, the early announcement increases consumption in 2009 because in the intertemporal Euler equation the announcement of a consumption tax increase is analogous to a reduction in the interest rate. Households understand that consumption in 2009 is cheaper than in 2010 and they vary their consumption path accordingly. What we find is that the announcement of the consumption tax rate hike in 2009 brings about an increase in consumption of 0.6 percent in 2009 in the representative household model economy and of 0.9 percent in the heterogeneous household model economy. Since in 2009 the consumption tax rates remain unchanged, these figures are the same both for consumption measured at market prices and for consumption measured at factor cost.

Then from 2010 onwards consumption measured at factor cost drops by about 1 percent in both reformed model economies. But consumption measured at market prices increases by about 0.6 percent in the representative household model economy from 2010 onwards and and between 0.9 percent and 1.0 percent in the heterogeneous household model economy. Again, this measure is misleading even though it is the one used by the national income and product accounts. The value of consumption measured at market prices increases only because the consumption tax collections increase. Household preferences are defined in terms of consumption at factor prices, and not in terms of consumption at market prices. Consequently the tax reform clearly reduces the contribution of consumption to household welfare.

The counterpart of the 2009 increase in consumption is that investment must be reduced. The announcement of the consumption tax hike made in 2009 brings about a reduction in aggregate investment of 3.2 percent in the representative household model economy and almost 4 percent in the heterogeneous household model economy. These large reductions in investment result in the reduction of both the capital stock and output fall in the following years. From 2010 onwards investment also falls, but in smaller amounts: about 1 percent in the representative household model economy, and between 3 percent and 1 percent in the heterogeneous household model economy.

6.3 Tax Revenues

Increasing the consumption tax rate increases total tax revenues from 2010 onwards, but it diminishes them in 2009. In the representative household model economy, the increase in tax revenues from 2010 onwards is of about 1.7 percent per year, and the reduction in tax revenues in 2009 is of about 0.6 percent. In the heterogeneous household model economy, the changes in tax revenues are somewhat larger: they increase by about 1.8 percent from 2010 onwards, and they fall by about 0.8 percent in 2009.

This sizable reduction in tax revenues in 2009 may seem puzzling since tax rates are kept constant during that year. But they are justified by the sizable increases in consumption in 2009 that we have already documented. Moreover, in 2009 there is also a reduction in labor hours, which reduces the revenues from labor income taxation. In addition, since less labor is used in production, the return to capital and the capital income tax collections also fall. The overall effect of these changes is that tax revenues decrease in 2009.

From 2010 onwards, we find that consumption tax revenues increase: in the representative household model economy by about 10.5 percent in the heterogeneous household model economy by about 11.5 percent. This is less than the 11.8 percent increase in the tax rate, because the reduction in aggregate consumption reduces the consumption tax base. This notwithstanding, most of the increase in the consumption tax revenues from 2010 onwards is largely offset by the reductions in capital and labor income tax revenues brought about by the reduced economic activity.

6.4 Elasticities

Our measure of the average value added tax rate for Spain in 2008 is 17 percent. An increase of 2 percentage points is equivalent to a relative increase in the consumption tax rate of 11.8 percent. However, our predictions for 2010 are that the revenues of the value added tax are smaller, between 10.5 percent and 11.5 percent depending on the model; that total tax collections increase by only about 1.7 percent; and that output at factor prices falls between 0.8 percent and 0.9 percent. We can use these numbers to compute elasticities of different variables to the increase in the consumption tax rate. We find that a 1 percent in the value added tax rate yields an increase of revenues from this tax of 0.90 percent in the representative household model economy and of 0.98 percent in the heterogeneous household model economy. This elasticity is close to one because aggregate consumption, the tax base, falls little. However, the elasticity of total government income is much smaller, an increase in 1 percent in the value added tax rate yields and increase of around 0.14 percent in total tax collections. This is because the share of the value added tax in total government income relatively small, and because the reduction in economic activity reduces the taxes collected by the other two instruments. Finally, the elasticity of output per capita at factor prices to the consumption tax increase is $--0.07$ percent. A final number worthy of memorizing is that when consumption taxes are used to increase government revenues, output per capita at factor prices falls by 0.5 percent for every 1 percent increase in government revenues.

6.5 Who Bears the Tax Burden of the Reform?

In Table 9 we report the distribution of the tax burden across various groups of households of our heterogeneous household model economy. First we classify the households according to their asset holdings into three categories: the poor, the middle class and the wealthy. Poor households are those whose wealth holdings are $a \in \{0, 10\}$, for the middle class they are $a \in \{11, 25\}$, and for the wealthy they are $a \in \{26, 50\}$. We find that in 2009, when the total tax burden falls, the households in the middle group are the ones whose tax burden is reduced the most, that they are followed by the poor, and that the tax burden of the wealthy is reduced the least. However, from 2010 onwards, when the tax burden increases, the poor households bear the largest share of the burden, followed by the wealthy. For example in 2010 the percentage differences in the tax burden for the poor, the wealthy, and the middle class are 3.91, 2.08, and 1.35 percent.

Next we classify the households into three age groups: the old, the middle-aged, and the young. Old households are those who belong to the 61+ age cohort, the middled-aged are those who belong to the 41–60 age cohort, and the young are those who belong to the 20–40 age cohort. Along the age dimension we find that, from 2010 onwards, the largest increase in the tax burden falls on the old, that it is followed by the increase in the tax burden of the middle-aged, and that the increases in the tax burden of the young are very small. For example in 2010 the percentage differences in the tax burden for the old, the middle-aged, and the young are 5.23, 1.25, and 0.33 percent.

Along the educational distribution we find that the largest share of the tax burden falls on the high school dropouts, followed by the college graduates, and the high school graduates —in 2010 their tax burdens increase by 1.92, 1.66, and 1.34 percentage points. And that along the distribution of employment types, the largest increase in the tax burden is born by the disabled households, followed by the retirees, while the increase in the tax burden of workers is sizably smaller —in 2010 their tax burdens increase by 7.92, 6.66, and 0.84 percentage points.

7 Concluding Comments

Our general model of the Spanish economy with heterogeneous agents predicts that the costs of increasing the value added tax in terms of output measured at factor prices are considerable: 0.71 percentage points in 2009 and around 1 percent in the next years. In addition, the increase in the tax burden is born mostly by the poor, the old, the high school dropouts, the disabled, and the retirees. These findings lead us to conclude that increasing the value added tax rate in Spain will probably have a non-trivial depressing effect on economic activity and that it will be clearly regressive. A similar exercise carried on with a model of the Spanish economy with a representative agent would have lead to very similar answer in terms of loss of gdp, but it would have been silent about the distribution of the tax burdens.

Of course, the quantitative results have to be taken with caution. Our model economies only contain one consumption good, and hence only one VAT tax rate. However, in reality there are many different types of goods and three different tax rates that apply. The VAT increase proposed by the Spanish government is of 2 percentage points for the goods under the general regime, of 1 percentage point for the goods on which the reduced VAT applies, and of 0 percentage points for the goods on which the super-redeuced VAT applies. In principle, low income households consume relatively more of those goods that are taxed at the reduced and super-reduced rates. Hence, the regressive nature of the reform may be partly offset by the composition of the basket of goods consumed by different households. In any case, we are not aware of any study using survey data on consumption (like the *Encuesta Contínua de Presupuestos Familiares*) that can inform us on the share of consumption goods of each type bought by the Spanish households, and how this share changes with household income, wealth, age or education.

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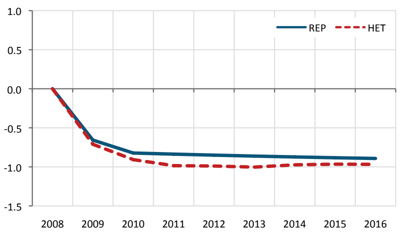
Table 8: The Consequences of the Reform in the Model Economies

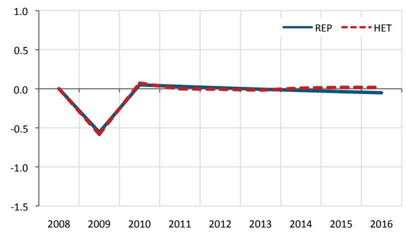
	2009	2010	2011	2012	2013	2014	2015	2016
				Output				
ΔY_R^*	–0.56	0.05	0.03	**0.01**	–0.01	–**0.02**	**–0.04**	**–0.05**
ΔY_H^*	–0.58	0.07	0.00	**–0.01**	–0.02	**0.01**	**0.02**	**0.02**
$\Delta\Delta$	0.02	–0.02	0.03	0.02	0.01	-0.03	-0.06	-0.07
ΔY_R	–0.66	–0.82	–0.84	–0.85	-0.86	–0.87	–0.88	–0.89
ΔY_H	–0.71	–0.91	–0.98	–0.99	–1.00	–0.97	–0.97	–0.97
$\Delta\Delta$	0.05	0.09	0.14	0.14	0.14	0.10	0.09	0.08
				Inputs				
ΔL_R	–1.01	–1.12	–1.11	–1.10	–1.09	–1.09	–1.08	–1.07
ΔL_H	–1.18	–1.30	–1.30	–1.26	–1.25	–1.18	–1.16	–1.14
$\Delta\Delta$	0.17	0.18	0.19	0.16	0.16	0.09	0.08	0.07
ΔK_R	0.00	–0.27	–0.33	–0.39	–0.44	–0.48	–0.52	–0.56
ΔK_H	0.00	–0.33	–0.58	–0.65	–0.72	–0.76	–0.80	–0.83
$\Delta\Delta$	0.00	0.06	0.25	0.26	0.28	0.28	0.28	0.27
				Consumption and Investment				
ΔC_R^*	0.63	0.60	0.58	0.55	0.53	0.51	0.50	0.48
ΔC_H^*	0.93	0.95	0.90	0.85	0.83	0.79	0.77	0.75
$\Delta\Delta$	–0.30	–0.35	–0.32	–0.30	–0.30	–0.28	–0.27	–0.27
ΔC_R	0.63	–1.09	–1.11	–1.14	–1.16	–1.18	–1.19	–1.21
ΔC_H	0.93	–0.85	–0.90	–0.94	–0.96	–1.01	–1.03	–1.05
$\Delta\Delta$	–0.30	–0.24	–0.21	–0.20	–0.20	–0.17	–0.16	–0.16
ΔI_R	–3.21	**–0.95**	–0.94	–0.94	–0.94	–0.94	–0.94	–0.94
ΔI_H	–3.90	**–3.18**	–1.44	–1.44	–1.21	–1.27	–1.16	–0.99
$\Delta\Delta$	0.92	**2.27**	0.53	0.53	0.30	0.36	0.25	0.08
				Government Revenues				
ΔT_{cR}	0.63	10.56	10.53	10.51	10.48	10.46	10.44	10.43
ΔT_{cH}	0.93	11.55	11.48	11.44	11.42	11.36	11.34	11.32
$\Delta\Delta$	–0.3	–0.99	–0.95	–0.93	–0.94	–0.90	–0.90	–0.89
ΔT_{kR}	–2.21	–2.12	–2.04	–1.96	–1.90	–1.85	–1.80	–1.76
ΔT_{kH}	–2.04	–2.56	–2.07	–1.91	–1.81	–1.62	–1.51	–1.46
$\Delta\Delta$	–0.17	0.44	0.03	–0.05	–0.09	–0.23	–0.29	–0.30
ΔT_{lR}^*	–0.66	–0.82	–0.84	–0.85	–0.86	–0.87	–0.88	–0.89
ΔT_{lH}^*	–1.13	–1.24	–1.33	–1.31	–1.33	–1.28	–1.29	–1.28
$\Delta\Delta$	0.47	0.42	0.49	0.46	0.47	0.41	0.41	0.39
$\Delta\Sigma T_R$	–0.58	1.71	1.70	1.69	1.68	1.67	1.67	1.66
$\Delta\Sigma T_H$	–0.76	1.73	1.74	1.78	1.79	1.85	1.86	1.89
$\Delta\Delta$	0.18	–0.02	–0.04	–0.09	–0.11	–0.18	–0.19	–0.23
ΔZ_R^*	–1.44	4.16	4.05	3.95	3.87	3.79	3.73	3.67
ΔZ_H^*	–1.73	3.92	3.92	3.97	3.97	4.06	4.08	4.10
$\Delta\Delta$	0.29	0.24	0.13	–0.02	–0.10	–0.27	–0.35	–0.43

*We have boldfaced the results that differ in sign or by more than 1 percentage points.

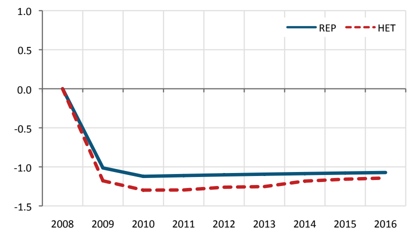
Figure 3: The Increase in the Value Added Tax in Both Models



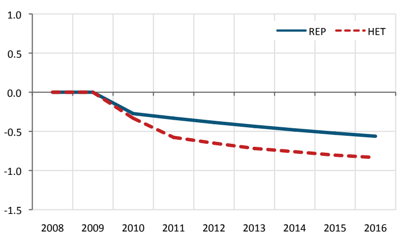
Panel A: Production at FC (Y_{fc})



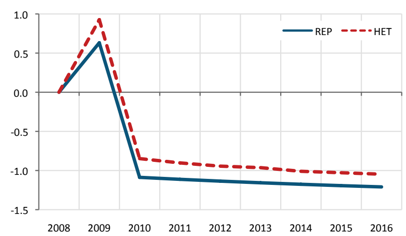
Panel B: Production at MP (Y_{mp})



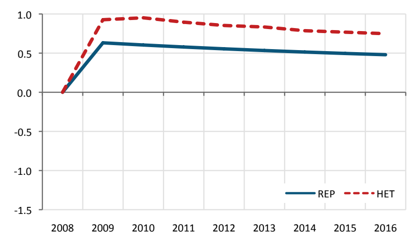
Panel C: Labor (L)



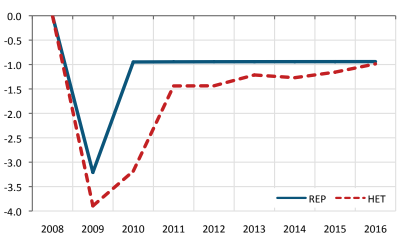
Panel D: Capital (K)



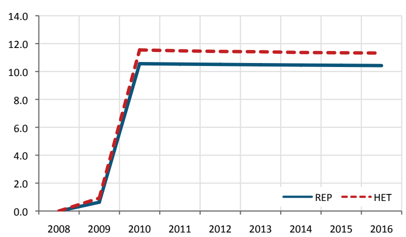
Panel E: Consumption at FC (C_{fc})



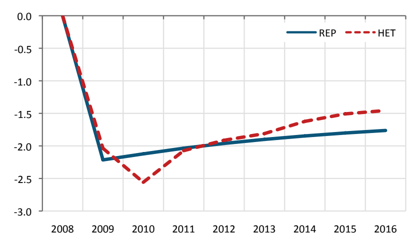
Panel F: Consumption MP (C_{mp})



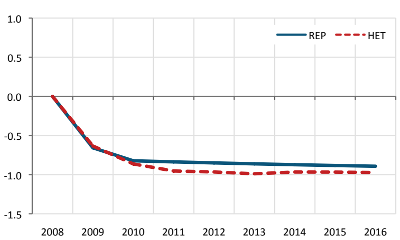
Panel G*: Investment (I)



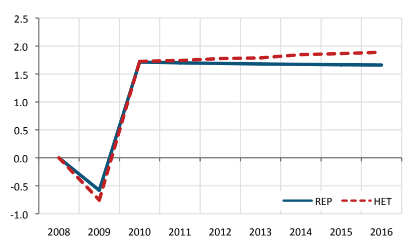
Panel H*: C Tax (T_c)



Panel I*: Y_k Tax (T_k)



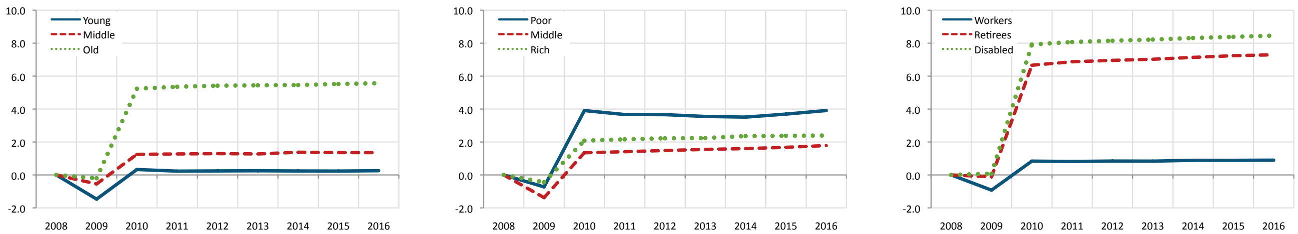
Panel J: Y_l Tax (T_l)



Panel K*: Total Tax Revenues

* Panels with different scales.

Figure 4: The Distribution of the Increase in the Value Added Tax



Panel A: Age

Panel B: Wealth

Panel C: Status

Table 9: The Distribution of the Tax Burden of the Reform in the Model Economies (%)

	2009	2010	2011	2012	2013	2014	2015	2016
Δ All Households	–0.76	1.73	1.74	1.78	1.79	1.85	1.86	1.89
Δ Poor[a]	–0.73	3.91	3.67	3.66	3.55	3.51	3.69	3.91
Δ Wealthy	–0.44	2.08	2.16	2.23	2.24	2.36	2.37	2.39
Δ Middle Class	–1.38	1.35	1.41	1.48	1.55	1.60	1.68	1.78
Δ Old[b]	–0.20	5.23	5.36	5.42	5.44	5.46	5.52	5.57
Δ Middle-aged	–0.54	1.25	1.27	1.29	1.27	1.38	1.36	1.35
Δ Young	–1.47	0.33	0.23	0.24	0.25	0.24	0.24	0.26
Δ Dropouts	–1.13	1.92	1.95	2.01	2.07	2.12	2.17	2.22
Δ College	–0.28	1.66	1.67	1.69	1.58	1.69	1.68	1.67
Δ Highschool	–0.78	1.34	1.31	1.34	1.39	1.44	1.42	1.45
Δ Disabled	0.08	7.92	8.07	8.15	8.22	8.31	8.39	8.46
Δ Retirees	–0.11	6.66	6.87	6.96	7.02	7.14	7.24	7.29
Δ Workers	–0.92	0.84	0.82	0.84	0.84	0.89	0.89	0.90

[a] Poor households are those whose wealth holdings are $a \in \{0, 10\}$, for the middle class they are $a \in \{11, 25\}$, and for the wealthy they are $a \in \{26, 50\}$.
[b] Old households are those who belong to the 61+ age cohort, the middled-aged are those who belong to the 41–60 age cohort, and the young are those who belong to the 20–40 age cohort.