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Capital goods, measured TFP and growth: The case of Spain

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ABSTRACT

The effect of investing in equipment and/or structures on TFP and long run growth is investigated here. We argue that economies can grow in spite of stagnant TFP if the investment rate is inefficiently high. We study the case of Spain where real GDP per worker grew at 2.74 percent annually and TFP was stagnant during 1996–2007. We show that low Spanish TFP is due to low ISTC and an inefficiently high investment in residential structures. We quantify the effect of the housing boom of the 2000s, the total cost of subsidies to residential structures in terms of TFP and income growth.

1. Introduction

One of the most striking facts about the Spanish economy is its ability to grow in spite of very low Total Factor Productivity. In particular, real GDP per working age person has grown at 2.74 percent during the period 1996–2007, on average, whereas Total Factor Productivity has been stagnant during that period. Here we argue that TFP is low because Investment Specific Technical Change is low. In spite of it, the Spanish economy has grown because investment in residential structures has been heavily subsidized. That is, investment in structures in Spain is inefficiently high. The resulting skewed capital portfolio towards structures contributes negatively to depress further measured TFP. This huge investment is the main reason for the increase in hours worked observed during the period 1996–2007.

To quantify the importance of this mechanism we have built a model economy along the lines of Greenwood et al. (1997) and Davis and Heathcote (2005). Market output is produced with equipment and non residential structures. Agents purchase residential stock to produce housing services. Our economy can be understood as one in which financial markets are perfect and there are no differences in human capital across agents. We have abstracted from any heterogeneity across households to concentrate in the main sources of growth of the economy. In our theory we take as exogenously given the fact that the relative prices of capital goods change over time. We apply the methodology of Kehoe and Prescott (2002) to study the growth patterns of Spain during the period 1970–2007.

We calibrate our model economy to match selected statistics of the Spanish economy during the period 1970–2007. When organizing the evidence, we find some facts about Spain that are very striking. The first fact is that Spain uses

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structures (both residential and business) very intensively. The ratio of business structures to output is 0.88, whereas it is 0.71 for the US for the period 1970–2007. The housing stock to output ratio is 1.69 in Spain versus 1.03 in the US. The difference is not due to higher prices in Spain, since the relative prices of residential structures have similar fluctuations in both countries. Spain also uses more intensively business equipment but Investment Specific Technical Change, as measured by the rate of change in the relative price of business equipment, is lower. We also find that the Spanish economy is standard in terms of the factorial distribution of income when compared to the US economy (see Cooley et al., 1995; Greenwood et al., 1997), and in line with previous studies of the Spanish economy, as Puch and Licandro (1997).

Our growth accounting exercise shows that a key factor when measuring TFP is whether the economy grows along a balanced growth path or not. If the economy is in a balanced growth path, measured TFP only depends on neutral progress and relative prices of capital, which convey information about ISTC. If the economy is not in a balanced growth path, measured TFP is affected by capital composition. In particular, if the share of housing in the total stock rises, TFP falls. This is a key issue in Spain, since it is in transition for most of the period 1970–2007 and residential structures comprise more than two thirds of total capital.

We take as our benchmark model economy one in which there are no distortions. In this way, we can quantify the effect of low ISTC on GDP growth, TFP, and capital composition. The main lesson we learn from this economy is that a neoclassical model economy cannot reconcile the observed low TFP growth rate and the observed GDP growth rate in Spain in absence of market distortions that rise the return to residential capital.

Given the evolution of the price of housing, a neoclassical model economy with perfect capital markets, calibrated in a reasonable way to reproduce the main features of the Spanish economy, does not generate enough housing demand to accumulate so much residential capital as we see in the data. Thus, we lend support to the conventional wisdom that Spanish growth is due to factor accumulation, not TFP growth. We also show that, in absence of TFP growth, a neoclassical economy does not accumulate as much capital as observed in the data to generate the observed GDP growth. Hence, we conclude that the investment rate observed in Spain during the period 1970–2007 is inefficiently high. We also give support to the idea that subsidies to the purchase of residential stock are at the heart of the high accumulation of residential structures. We introduce a wedge as a subsidy to the purchase of residential structures. This alternative economy is able to match at the same time the low TFP of the data and the high GDP growth observed. The estimated wedge is about 50 percent of the price of residential structures. García-Montalvo (2012) estimates that the subsidy to the purchase of the first home is about 10 to 20 percent of the value of the house. The total cost of this subsidy amounts to 3.5 percent of GDP in our model economy. García-Montalvo (2012) estimates a total cost of 1 percent of GDP since 1990. Our estimates are of the same order of magnitude. We also need to take into account that we are abstracting from distortionary taxation, which may bias our estimate of the subsidy upwards. It is interesting to note the connection between investment in residential stock and hours worked. By subsidizing the purchase of houses we are rising the marginal utility of non durable consumption, which lowers the cost of leisure. As a result, the supply of hours increases and hours worked increase, too, as we see in the data. This result is related to Fisher (2007) who finds evidence for household capital being complementary to labor and business capital at the business cycle frequency.

We have run a series of counterfactual economies to have a sense of which type of policies may help to boost TFP and, therefore, GDP growth. We find that house price booms (in absence of subsidies) lower GDP growth through hours worked and lower accumulation of residential capital, but TFP is not significantly affected. Business structures price booms do have an extra effect on TFP, since it amounts to a fall in Investment Specific Technical Change. Adding higher ISTC in business equipment rises TFP and output, but does not affect much hours worked. This is so because we have calibrated our model economy to reproduce the fact that average hours worked per working age person in Spain is low. Structural unemployment is very high in Spain, and tackling this issue is out of the scope of this paper.

Our paper belongs to that branch of the literature that studies great recessions, such as Kehoe and Prescott (2002), Conesa et al. (2007), and others. We also contribute to the literature on growth accounting and Investment Specific Technical Change (see, for instance, Greenwood et al., 1997; Oulton, 2007) and illustrate the connection between ISTC and the standard measure of TFP. The advantage of our multisector economy is that allows us to isolate the sources of low TFP. Moreover, it allows us to quantify the cost in terms of measured TFP of a rise in the relative price of structures. We find that this cost is significant. Chen et al. (2006) use a similar approach to understand the differences in the saving rate in Japan versus the US economy in a one sector growth model environment. In our model we differentiate between equipment and structures to account for the forces behind the evolution of the TFP.

Other papers has quantified the impact of ISTC on output growth in Spain. Martínez et al. (2008) use a dynamic general equilibrium model with six different capital inputs into the production function to quantify the impact of the information and communication technology (ICT) on growth of market output in Spain between 1995 and 2002 (they exclude housing from their analysis). However, their analysis assumes that the Spanish economy is in a balanced growth path during this period. Our paper shows that it is important departing from this assumption. The reason is that in a balanced growth path there are no changes in the mix of capital, as opposed to a transition. This compositional effect is important to understand the behavior of measured TFP in Spain.

The rest of the paper is organized as follows: Section 2 presents our benchmark model economy. In Section 3 we show our growth accounting methodology. Section 4 discusses the data used and some particular features of the growth patterns in Spain as well as our calibration strategy. Section 5 presents our main results. Finally, Section 6 concludes.

2. The model economy

In this section we present our model economy, the equilibrium definition and some properties of the balanced growth path. Ours is an infinite horizon economy. Time is discrete.

2.1. Preferences and endowments

There is a representative household that seeks to maximize expected discounted lifetime utility,

$$\sum_{t=0}^{\infty} \beta^t N_t \left[\ln(c_t) + \phi \frac{(\hbar - h_t)^{1-\sigma}}{1-\sigma} \right] \tag{2.1}$$

where N_t is the size of the household at time t, c_t is a composite consumption good, and h_t is hours worked in the market per household member. The size of the household, N_t, evolves exogenously. The composite c_t is a mix of a non durable consumption good and services, $c_{mt} + g_t$, and housing services, c_{ht}:

$$c_t = (c_{mt} + g_t) c_{ht}^{\gamma}. \tag{2.2}$$

The non durable consumption good is either acquired in the market, c_{mt}, or provided by the government, g_t. In order to obtain housing services the household needs to combine housing (residential structures) and durable consumption goods. Hence,

$$c_{ht} = \Psi\, k_{ht}^{\psi} k_{dt}^{1-\psi}. \tag{2.3}$$

2.2. Technology

The production of final output, Y_m, requires of labor services, H, and two types of capital, equipment and structures. Production takes place in accordance to the aggregate production function

$$Y_{mt} = Z_t K_{et}^{\alpha_e} K_{st}^{\alpha_s} H_t^{1-\alpha_e-\alpha_s}, \quad 0 < \alpha_e,\ \alpha_s,\ \alpha_e + \alpha_s < 1. \tag{2.4}$$

The variable Z_t is a measure of neutral technical progress. There is a technology that allows agents to transform final good of period t into Θ_{it} units of new capital of type i,

$$X_{it}^{i} = \Theta_{it}\, I_{it}, \quad i = e, s, d, h, \quad \text{for all } t, \tag{2.5}$$

where i stands for equipment, structures, housing and durable consumption goods. Capital accumulates according to the law,

$$K_{i\,t+1} = X_{it} + (1-\delta_i) K_{it}, \quad i = e, s, d, h, \quad \text{for all } t. \tag{2.6}$$

The depreciation rate is denoted as δ_i. Changes in Θ_{jt}, $j = e, s, d, h$, formalizes the notion of Investment Specific Technical Change (ISTC hereafter). As in Greenwood et al. (1997), technical change makes new capital either less expensive or better than old capital, allowing to increase consumption.

2.3. Market arrangements and government policy

The household is the owner of all technologies and production factors. Additionally, the household can use a bond to save or borrow. Its real return, in units of the non durable consumption good, is r_t^a. This is a closed economy.

We consider two different institutional frameworks regarding the labor market. In the first framework the workweek to produce the private market good is flexible. In the second framework the workweek is fixed and equal to h_0. In the latter case we assume that there is a perfect insurance market against the risk of being unemployed. Agents work with probability π_t.

There is a government that may subsidize (tax) expenditures in housing (structures) at the rate ξ_{it}, $i = h, s$. Additionally, the government finances public expenditures. To focus our attention on the effects of the distortion implied by the housing subsidy, we assume that the subsidy and government expenditures are all financed with lump-sum taxes. The government's budget is balanced every period.

For simplicity, we assume that there are no rental markets where to buy housing services. In other to obtain them, agents need to buy housing stock and consumer durable goods. Given that there are no frictions in this economy, this assumption is not restrictive. See, for instance, Díaz and Luengo-Prado (2008).

2.4. Competitive equilibrium

The problem solved by the firm that produces the final good is static:

$$\max_{K_{et},K_{st},H_t} Z_t K_{et}^{\alpha_e} K_{st}^{\alpha_s} H_t^{1-\alpha_e-\alpha_s} - r_{et}\, K_{et} - r_{st}\, K_{st} - w_t\, H_t. \tag{2.7}$$

Firms producing equipment, structures, housing and durable goods are perfectly competitive and solve the problem:

$$\begin{aligned} &\max_{X_{jt},I_{jt}} \quad q_{jt}\, X_{jt} - I_{jt} \\ &\text{s.t.} \quad 0 \le X_{jt} \le \Theta_{jt}\, I_{jt}. \end{aligned} \tag{2.8}$$

The representative household's problem depends on the institutional framework. In the case of a flexible workweek, its problem is

$$\begin{aligned} &\max_{c} \quad \sum_{t=0}^{\infty} \beta^t N_t \left[\ln(c_t) + \phi \frac{(\hbar - h_t)^{1-\sigma}}{1-\sigma} \right] \\ &\text{s.t.} \quad 0 \le c_t \le (c_{mt} + g_t) c_{ht}^{\gamma}, \\ &\qquad 0 \le h_t \le 1, \\ &\qquad 0 \le c_{ht} \le \Psi\, k_{ht}^{\psi} k_{dt}^{1-\psi}, \\ &\qquad c_{mt} + \sum_j q_{jt}\, x_{jt} + \frac{N_{t+1}}{N_t} a_{t+1} - a_t \le w_t\, h_t + r_{et} k_{et} + r_{st} k_{st} + r_{at} a_t - \tau_t + \xi_{st}\, q_{st}\, x_{st} + \xi_{ht}\, q_{ht}\, x_{ht}, \\ &\qquad 0 \le \frac{N_{t+1}}{N_t} k_{jt+1} \le x_{jt} + (1-\delta_j) k_{jt} \quad \text{for all } j, \\ &\qquad a_{t+1} \ge -\underline{a}, \\ &\qquad k_{j0}, j = e, s, d, h, \text{ and } a_0 \text{ given,} \end{aligned} \tag{2.9}$$

where ξ_{jt} denotes the subsidy given to investment in housing (or structures). If the workweek is fixed and equal to h_0, the utility function should be written taking into account the fact that the household buys a labor participation lottery,

$$\sum_{t=0}^{\infty} \beta^t N_t \left[\ln(c_t) + (1-\pi_t)\phi \frac{\hbar^{1-\sigma}}{1-\sigma} + \pi_t\, \phi \frac{(\hbar - h_0)^{1-\sigma}}{1-\sigma} \right] \tag{2.10}$$

and average hours worked per worker, h_t, are equal to $\pi_t\, h_0$.

Definition 1. A competitive equilibrium for this economy, given the government policy $\{\xi_{st}, \xi_{ht}, \tau_t, g_t, I_t^g\}_{t=0}^{\infty}$, is a sequence of prices, $\left\{w_t, r_{et}, s_{et}, \left(q_{jt}\right)_j, r_{at}\right\}_{t=0}^{\infty}$, an allocation for the firm producing the final good, $\{Y_{mt}, K_{et}, K_{st}, L_t\}_{t=0}^{\infty}$, an allocation for the firms producing capital good $j = e, s, d, h$, respectively, $\{X_{jt}, I_{jt}\}_{t=0}^{\infty}$, and an allocation for the representative household, $\left\{c_t, \pi_t, (x_{jt}, k_{jt+1})_j, a_{t+1}\right\}_{t=0}^{\infty}$ such that:

1. Rental prices of factors are equal to their marginal productivities.
2. The price of investment in capital good j is $q_{jt} = 1/\Theta_{jt}$, $j = e, s, d, h$.
3. The allocation $\left\{c_t, \pi_t, (x_{jt}, k_{jt+1})_j, a_{t+1}\right\}_{t=0}^{\infty}$ solves the household's problem given the government policy and the sequence of prices.
4. Government's budget is balanced, $N_t\, \tau_t = \xi_{st}\, q_{st}\, K_{st} + \xi_{ht}\, q_{ht}\, K_{ht} + N_t\, g_t + I_t^g$.
5. Markets clear:
   (a) $K_{it} = N_t\, k_{it}$, $i = e,\ s,\ d,\ h$,
   (b) $H_t = N_t\, h_t$,
   (c) $X_{jt} = N_t\, x_{jt}$, $j = e,\ s,\ d,\ h$,
   (d) $Y_{mt} = N_t\, c_t + \sum_j I_{jt} + N_t\, g_t + I_t^g$.

Notice that we have assumed that the government expends resources in a public consumption good g_t and another item called I_t^g. We do this to take into account that the government may also spend resources in items that do not yield utility to the household. We do this for purely quantitative reasons to match the data.

2.5. The balanced growth path

This economy has a balanced growth path where the growth rate of output is a weighted geometrical average of the growth rate of neutral technical progress and ISTC.

Proposition 1. *Assume that population grows at a constant rate, $N_{t+1}/N_t = n > 0$, and that the government policy is invariant over time, $\xi_{it} = \xi_i$, $i = s,\ h$, and that $N_t\ g_t$ and I_t^g are constant fractions of market output, Y_{mt}, for all t. Assume further that neutral progress as well as investment specific technical change all grow at a constant rate, $Z_{t+1}/Z_t = 1+\zeta$, $\Theta_{jt+1}/\Theta_{jt} = 1+\theta_j$, $j = e,\ s,\ d,\ h$. Then, this economy has a balanced growth path along which all variables grow at a constant rate*:

1. *Output and consumption per capita grow at the rate*

$$\frac{y_{mt+1}}{y_{mt}} = 1+g_y = (1+\zeta)^{1/(1-\alpha_e-\alpha_s)}(1+\theta_e)^{\alpha_e/(1-\alpha_e-\alpha_s)}(1+\theta_s)^{\alpha_s/(1-\alpha_e-\alpha_{bs})}, \tag{2.11}$$

2. *capital good j grows at the rate*

$$\frac{k_{jt+1}}{k_{jt}} = 1+g_j = (1+\theta_j)\left(1+g_y\right), \tag{2.12}$$

3. *the return to equipment and structures satisfy, respectively, the non-arbitrage condition*

$$\frac{1+g_y}{\beta} = (1+r_a) = \frac{(1-\delta_e)q_{et+1}+r_{et+1}}{q_{et}} = \frac{(1-\xi_s)(1-\delta_s)q_{st+1}+r_{st+1}}{(1-\xi_s)q_{st}}, \tag{2.13}$$

4. *the return to consumer durable goods and residential capital satisfies*

$$(1+r_a) = \frac{(1-\delta_d)q_{dt+1}+\gamma(1-\psi)\dfrac{c_{mt+1}+g_{t+1}}{k_{dt+1}}}{q_{dt}} = \frac{(1-\xi_h)(1-\delta_s)q_{ht+1}+\gamma\,\psi\,\dfrac{c_{mt+1}+g_{t+1}}{k_{ht+1}}}{(1-\xi_h)q_{ht}}, \tag{2.14}$$

5. *and per capita hours worked are constant.*

Expression (2.11) shows that the lower the level of technical change specific to either type of capital, the lower is the growth of output. In our theory, the evolution of the relative price of capital is governed by the evolution of ISTC. Thus, the lower the fall in the relative price of capital, the lower is ISTC and the growth rate of output. We will measure this effect in Section 5.3 when we assess quantitatively the effect of rising relative prices of structures on measured TFP.

3. Growth accounting and the measurement of TFP

In this section we want to discuss our growth accounting procedure. First of all, we need to distinguish between market output and GDP, since they are different things in this economy.

3.1. Market output

Let us write our production function (2.4) in per capita terms:

$$y_{mt} = Z_t\ k_{et}^{\alpha_e} k_{ts}^{\alpha_s} h_t^{1-\alpha_e-\alpha_s}. \tag{3.1}$$

Following Hayashi and Prescott (2002), it is possible to rewrite the production function as:

$$y_{mt} = Z_t^{1/(1-\alpha_e-\alpha_s)} q_{et}^{-\alpha_e/(1-\alpha_e-\alpha_s)} q_{st}^{-\alpha_s/(1-\alpha_e-\alpha_s)} \left(\frac{q_{et}k_{et}}{y_{mt}}\right)^{\alpha_e/(1-\alpha_e-\alpha_s)} \left(\frac{q_{st}k_{st}}{y_{mt}}\right)^{\alpha_s/(1-\alpha_e-\alpha_s)} h_t. \tag{3.2}$$

We use this expression to obtain the series of neutral technological progress in the data. We will also use this expression to measure the contribution of neutral progress, Z_t, ISTC, capital accumulation and hours to output growth. This is not the conventional procedure of growth accounting, which is based in Solow (1957), where all capital is aggregated in units of final good. Comparing both specifications:

$$Y_{mt} = Z_t K_{et}^{\alpha_e} K_{st}^{\alpha_s} H_t^{1-\alpha_e-\alpha_s}, \tag{3.3}$$

$$Y_{mt} = A_{mt}\ \mathcal{K}_{mt}^{\alpha} H_t^{1-\alpha}. \tag{3.4}$$

The stock $\mathcal{K}_{mt}$ is aggregate business capital, $\mathcal{K}_{mt} = q_{et}\ K_{et} + q_{st}\ K_{st}$, measured in units of final output. We can also rewrite the production function as

$$y_{mt} = A_{mt}^{1/(1-\alpha)}\left(\frac{\mathcal{K}_{mt}}{y_{mt}}\right)^{\alpha/(1-\alpha)} h_t, \quad \alpha = \alpha_e + \alpha_s. \tag{3.5}$$

Both specifications of production functions produce the same growth accounting along the balanced growth path, but not in an economy in transition (this is the case in Spain for most of the period studied in this paper). The growth accounting exercise in (3.4) computes as Total Factor Productivity (TFP) the factor:

$$A_{mt} = Z_t\, q_{et}^{-\alpha_e} q_{st}^{-\alpha_s} \left(\frac{q_{et}\, K_{st}}{\mathcal{K}_{mt}}\right)^{\alpha_e} \left(\frac{q_{st}\, K_{st}}{\mathcal{K}_{mt}}\right)^{\alpha_s}. \tag{3.6}$$

Along the balanced growth path the capital to output ratio is constant (when capital is measured in units of the final good), and the composition of capital is constant. Thus, TFP is given by the combination of neutral progress and ISTC, $Z_t^{1/(1-\alpha_e-\alpha_s)} q_{et}^{-\alpha_e/(1-\alpha_e-\alpha_s)} q_{st}^{-\alpha_s/(1-\alpha_e-\alpha_s)}$. Out of the balanced growth path changes in the composition of capital will affect the measurement of TFP, even if the aggregate stock does not change when measured in units of the final good. Let us turn now to GDP.

3.2. Gross domestic product

Growth accounting out of the balanced growth path is even more problematic when we turn to GDP. Notice that, as it is a common practice in all developed countries, GDP is constructed adding to market output the value of services yielded by housing. This is done using a rental equivalence approach; see, for instance, Díaz and Luengo-Prado (2008). Thus, we can write,

$$GDP_t = Y_{mt} + r_{ht} K_{ht}. \tag{3.7}$$

The rental price is obtained as the shadow price of housing services, shown in (2.14). Hence,

$$r_{ht} = \gamma\, \psi\, \frac{c_{mt} + g_t}{k_{ht}}. \tag{3.8}$$

Then, GDP is given by

$$GDP_t = Y_{mt} + \gamma\, \psi\, N_t (c_{mt} + g_t). \tag{3.9}$$

Let us denote as s_t the investment rate out of market output. Thus,

$$GDP_t = Y_{mt}[1 + \gamma\, \psi(1 - s_t)]. \tag{3.10}$$

It follows that we can rewrite GDP in per capita terms as

$$gdp_t = [1 + \gamma\, \psi(1 - s_t)](Z_t)^{1/(1-\alpha_e-\alpha_s)} q_{et}^{-\alpha_e/(1-\alpha_e-\alpha_s)} q_{st}^{-\alpha_s/(1-\alpha_e-\alpha_s)} \left(\frac{q_{et} k_{et}}{y_{mt}}\right)^{\alpha_e/(1-\alpha_e-\alpha_s)} \left(\frac{q_{st} k_{st}}{y_{mt}}\right)^{\alpha_s/(1-\alpha_e-\alpha_s)} h_t. \tag{3.11}$$

Notice that the housing stock affects GDP through the investment rate. The larger the investment rate, the lower is non housing consumption, which reduces the rental price of the residential stock and, therefore, its market value. Again, to calculate TFP we need to look at GDP through the lenses of the one sector growth model, which now includes residential capital as part of the total stock of capital:

$$GDP_t = [1 + \gamma\, \psi(1 - s_t)]\, Z_t K_{et}^{\alpha_e} K_{st}^{\alpha_s} H_t^{1-\alpha_e-\alpha_s}, \tag{3.12}$$

$$GDP_t = A_t\, \mathcal{K}_t^{\varphi} H_t^{1-\varphi}, \tag{3.13}$$

where $\mathcal{K}_t = q_{et}\, K_{et} + q_{st}\, K_{st} + q_{ht}\, K_{ht}$, and φ is calibrated to match the share of capital in GDP. Thus, $\varphi = (\alpha_e + \alpha_s)(1 - \varphi_h) + \varphi_h$, where φ_h is given by the share of residential capital in GDP. Thus,

$$A_t = [1 + \eta\, \psi(1 - s_t)]\, Z_t\, q_{et}^{-\alpha_e} q_{st}^{-\alpha_s} \left(\frac{q_{et}\, K_{st}}{\mathcal{K}_{mt}}\right)^{\alpha_e} \left(\frac{q_{st}\, K_{st}}{\mathcal{K}_{mt}}\right)^{\alpha_s} \left(\frac{\mathcal{K}_{mt}}{\mathcal{K}_t}\right)^{\alpha_e+\alpha_s} \left(\frac{H_t}{\mathcal{K}_t}\right)^{\varphi-\alpha_e-\alpha_s}. \tag{3.14}$$

Which can be written as

$$A_t = [1 + \eta\, \psi(1 - s_t)]\, A_{mt}^{1-\varphi_h} \left(\frac{\mathcal{K}_{mt}}{\mathcal{K}_t}\right)^{\alpha_e+\alpha_s} \left(\frac{H_t}{\tilde{\mathcal{K}}_t}\right)^{\varphi-\alpha_e-\alpha_s}. \tag{3.15}$$

and $\tilde{\mathcal{K}}_t = \mathcal{K}_t\, A_{mt}^{-1/(1-\alpha_e-\alpha_s)}$.

Along the balanced growth path TFP, denoted as A_t, grows at the same rate that the factor $A_{mt}^{1-\varphi_h}$, but out of the balanced growth path, both factors may diverge. For instance, a shift in the composition of total capital $\mathcal{K}_t$ towards housing that leaves unchanged the composition of business capital, $\mathcal{K}_{mt}$, and the saving rate, s_t, would produce a fall in TFP. A rise in the investment rate in housing would also show up as a fall in TFP. Moreover, a fall in the (detrended) labor to capital ratio, $H_t/\tilde{\mathcal{K}}_t$, (which is the case in a transition towards a balanced growth path) will also produce a fall in TFP. This is the case because the share of labor in market output is larger than the labor share in GDP. Thus, when the hours to capital ratio increase, some of its effect is attributed to TFP.

4. Calibration and solution method

In this section we describe the data used and the procedure to calibrate our benchmark model economy.

4.1. The data

Our data sources are the *Instituto Nacional de Estadística* (the Spanish statistical office), the *Ministry of Public Finance* and *EU KLEMS*. For a description of the data see Appendix A. We use the period 1970–2007. We stop in 2007 because we do not have a theory to account for the Great Recession.

4.2. The stock of capital

We have distinguished four types of capital, equipment, structures, housing and consumer durable goods. In the data we have their ready counterparts. We are simplifying labels and by *structures* we refer to private non residential structures and by *housing* we refer to private residential structures. We have taken the data from EU KLEMS, which provides information on investment, the stocks, and implicit price deflators. We have not included capital owned by the government but privately owned infrastructures, such as private highways, are included in our measure of structures. We have added the stock of consumer durable goods to give our model economy the best chance to replicate the patterns of the data. In Appendix A we explain our procedure to construct the composite *equipment*, and the stock of consumer durable goods. The upper panel of Fig. 1 shows the ratio of capital to GDP for each category. For illustrative purposes, we show the same ratio for the US economy. As we can see, Spain is more intensive in capital than the US economy. The average ratio of structures in Spain is 0.88, whereas the same ratio is 0.71 in the US. It is very noticeable the difference in the housing stock, which is 1.69 times the volume of GDP in Spain, whereas it is about 1.03 in the US. As for equipment, the most striking feature of the data is that the ratio shows a significant fluctuation in Spain, going from 0.65 in 1970 to almost 0.4 in 1996.

Fig. 1 also shows the relative prices of each capital category (in units of non durable consumption goods and services). The base year is 1996. The relative price of housing is shown in Fig. 1(f). Notice that this price increased by about 78 percent throughout the entire period 1970–2007. It is interesting to note that there were two small booms before the 2000s: the price reached to 114 in 1979, and there was a minor surge in 1990, when the price rose to 106.30 prior to the peak in 2007, reaching the value 140. To put the numbers in context, we have calculated the same relative price for the US economy.[1] We have normalized the relative prices in the same manner so that 1996 is the base year for both. Fig. 1(f) shows that both prices have a very similar evolution, being the peak in both countries in 2006; the price reaches 140 in Spain and 120.78 in the US. A somewhat different pattern has the relative price of business structures, shown in Fig. 1(e). The relative price of structures in Spain fluctuates less than that of housing. It reaches a maximum in 1974, being 117, and its minimum value is 98.50 in 1998. In the US, however, it fluctuates even more than that of housing, increasing more than its counterpart in Spain during the last boom. Very different, though, is the behavior of the relative price of equipment, shown in Fig. 1(d). It exhibits a downwards trend, which we assume that is due to the existence of ISTC. We compare the price in Spain with its counterpart in the US. As in the case of structures, the base year is 1996. It is interesting to note, although beyond the scope of this paper, that both prices have very similar fluctuations implying that business cycles are very correlated. The fall in the relative price in the US is significantly higher in the US. This implies that ISTC and, *ceteris paribus*, measured TFP are higher in the US than in Spain. The implied annualized growth rate of ISTC in business equipment for the period 1970–2008 has been 3.37 percent in Spain, whereas in the US has been 4.82 percent. We do not know why the relative price is different but our first candidate is the different sectoral composition of aggregate value added in US, where IT sectors must have a larger share than in Spain.

We do neither plot the stock of durable goods to GDP neither its relative price to not clutter the presentation of facts. The mean of the capital to GDP ratio for Spain and the US are, respectively, 0.29 and 0.34, which some cyclical fluctuations. As in the case of equipment, the relative price of consumer durable goods falls over time, but the fall in the US is more pronounced. The implied annualized rate for the period 1970–2008 has been 1.18 percent in Spain, whereas in the US has been 2.89 percent. Finally, we show in Fig. 2(c) various statistics related to consumption. The line called c shows the share of expenditures in private non durable consumption goods and services in GDP. Notice that it decreases over time. The sum $c+g$ adds to c the amount of government expenditures in consumption goods (i.e., excluding public investment). Notice that this share has no trend. This is why we have assumed in the model that the public good is a perfect substitute for private non durable consumption. Additionally, we have plotted $c+nx$, which adds to the previous measure $c+g$ the trade balance in the data. This is the appropriate statistic against which we should compare the measure of private non durable consumption delivered by our theory since ours is a closed economy. Notice, again, that the statistic $c+g+nx$ has no trend.

4.3. Calibration of the benchmark economy

Our benchmark economy is one where the subsidy to investment in either structures or residential stock is zero. The model economy is calibrated so that selected model statistics match their counterparts in the data for the period 1970–2007. The Spanish economy has experienced important institutional changes during the period 1970–1996. In particular, the labor market suffered various legal changes. In 1980 new legislation was introduced intended to reduce the flexibility in the

[1] Recall that this relative price does not include the value of land, which is netted out of the price of houses following the tradition of not including the value of non-reproducible assets in National Accounts.

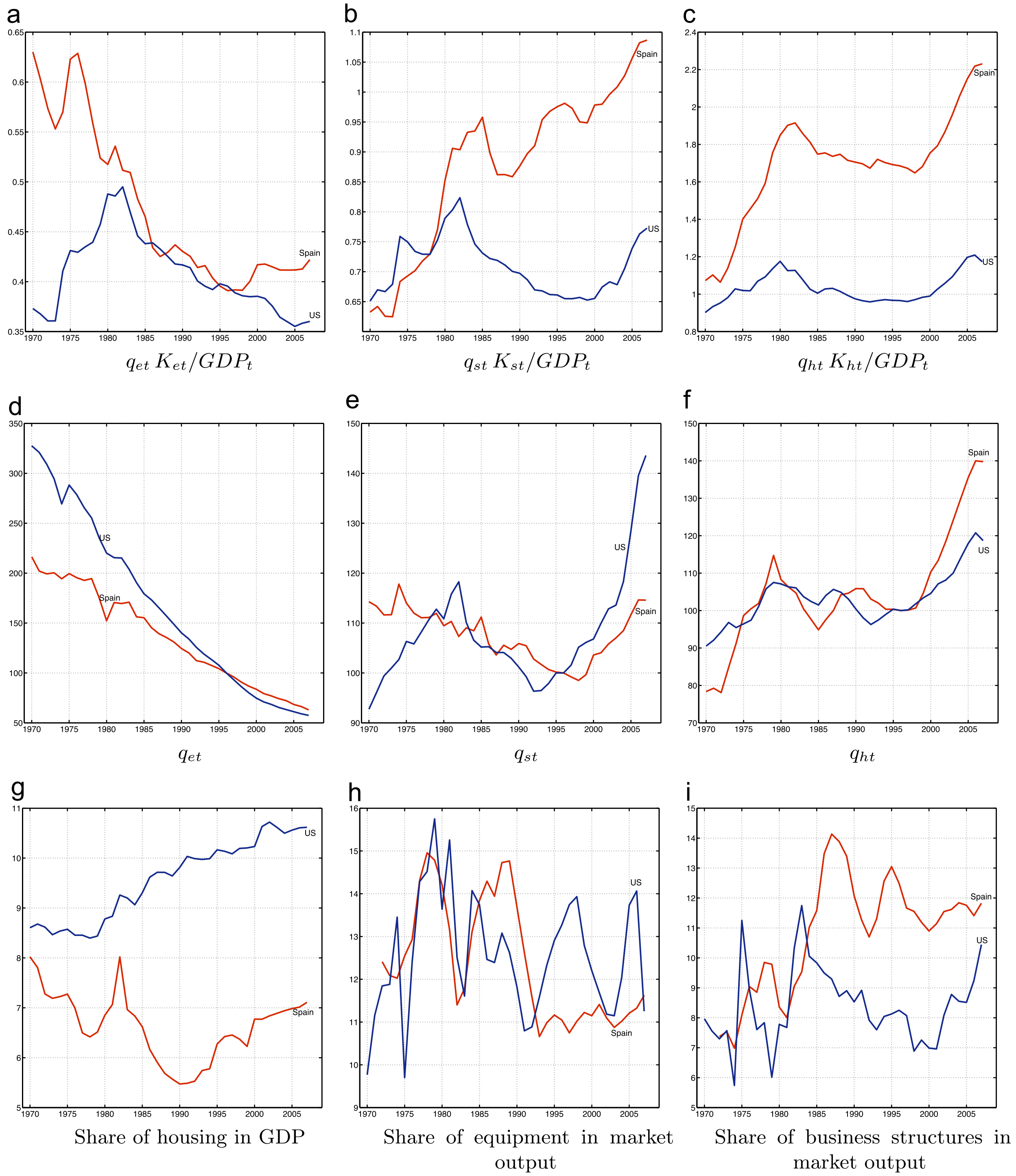

Fig. 1. Spain 1970–2007 (I).

workweek and rise severance payments. In 1984 new legislation allowed the extensive use of temporary contracts (short term contracts with low severance payments). This duality of the labor market is at the core of the volatility of employment in Spain (see, for instance, Bentolila et al., 2012). In order to capture, albeit in a crude manner, these changes, we assume that there is an institutional change in 1984. Prior to that date, the workweek is flexible. From 1984 onwards, the workweek is fixed and workers buy an unemployment lottery.

The depreciation rates of each type of capital are directly calculated as weighted averages of the depreciation rates calculated in EU KLEMS for the corresponding categories comprised, respectively, in *Equipment* and *Structures*, as discussed in Appendix A. In particular, the depreciation rate of equipment is $\delta_e = 0.1361$, that of structures is $\delta_s = 0.0277$, the one of durable consumption goods iso $\delta_d = 0.21$, and that of housing is $\delta_h = 0.0077$.

In order to calibrate factor shares in market output we need first to compute market output. We have taken from Márquez (2004) and the *Instituto Nacional de Estadística* the series of consumption expenditures in housing services. This series comprises the services of rental housing as well as the imputed services of owner occupied housing (computed using a rental equivalence approach, see Díaz and Luengo-Prado, 2008).[2] We have called this item $r_{ht}\, K_{ht}$. Our measure of market output, Y_{mt}, is GDP minus housing services, $Y_{mt} = GDP_t - r_{ht}\, K_{ht}$. Fig. 1(g) shows the share of housing services in GDP in Spain and the US (we have proceeded accordingly for the US). The share is larger in the US and increasing over time. In Spain the share is lower and falls until 1990, period at which it starts rising again. The average of the share in Spain is 6.63 percent, versus 9.56 in the US. Hence, the contribution of housing capital to GDP growth must be lower in Spain than the US. To calculate the shares of equipment and structures in market output we use the information provided by EU KLEMS about compensation to business equipment and non residential structures. EU KLEMS calculates the compensation of each type of capital in this category using a non arbitrage condition (see O'Mahony and Timmer, 2009). This is also what Greenwood et al. (1997) do, since there is no way of distinguishing the return to business equipment from that of business structures in the data. The evolution of those shares is shown in Figs. 1(h), and (i), respectively. We have computed those of the US using a non arbitrage condition. The average of the share of equipment is 0.1238, which is very similar to that for the US economy, 0.1257. Both shares display some cyclical fluctuations, more so the US economy, whereas in Spain the share remains below that of the US after the mid 1990s. Thus, we set $\alpha_e = 0.1238$. The share of business structures is shown in Fig. 1(e). Again, this share displays fluctuations in both economies. The average for Spain is 0.1065, whereas it is lower for the US, 0.8390. Their cyclical behavior is different, since the value of the share in Spain rises after the mid 1990s, mirroring the fall in the share of equipment. Thus we set $\alpha_s = 0.1065$. As a result, the labor share in market output is lower in Spain than in the US, 76.96 versus 79.04 percent.

In order to choose a value for $\hbar$, the endowment of hours, we follow the same approach that Conesa et al. (2007) and set a constant value of $\hbar = 5200$. This value stands for the annual endowment of hours per working age person. We have assumed that $\sigma = 1$. The parameters that govern the response of labor supply are ϕ, the weight of leisure in utility, and h_0, the length of the workweek. The parameter ϕ is calibrated so that average hours worked per capita (as percentage of the total endowment) in 1970 match their counterpart in the data. The number is $\phi = 4.1654$. We calibrate h_0 so that average hours worked in the model for the period 1984–2007 match their counterpart in the data. The value is 3100. The discount factor is chosen so that the model economy replicates the observed equipment to market output ratio. The implied value is $\beta = 0.9536$. We calibrate γ and ψ, the parameters that govern the utility yielded by the services of housing and durable consumption goods, to match the observed durable goods to market output ratio and the share of housing in GDP. Thus, $\gamma = 0.2550$, and $\psi = 0.4327$. Government expenditures are financed with lump-sum taxes. Table 1 summarizes the targets of the model economy and the implied values of the calibrated parameters. The series for neutral technical progress, Z_t, is obtained using a standard Solow decomposition and it shown in Fig. 2(b).

4.4. Solution method

Notice that we are not assuming that the Spanish economy is at a balanced growth path during the period 1970–2007. We are calibrating our benchmark model economy to match selected patterns of an economy in transition. Thus, we need to take a stand about the *beliefs* of the representative household about the growth path of our model economy after 2007. We assume the following: neutral progress, Z_t, grows at the average growth rate of the period 1970–2007 after 2007. Population grows thereafter at its rate in 2007. The relative price of structures and housing, q_{st}, and q_{ht}, are constant thereafter and equal to their value in 2007. The relative price of equipment and consumer durable goods, q_{et} and q_{dt}, fall at their average rate of the previous period 1970–2007. Public expenditures, both consumption and investment, are constant as a fraction of output, and this ratio is that of 2007.

Solving for an equilibrium implies obtaining sequences of output, consumption, equipment, structures, and hours worked such that these sequences solve the system of equations that characterize the equilibrium given initial conditions for the stock of the four types of capital and given government consumption, g_t, and government investment, I_t^g. Our numerical solution procedure follows Conesa et al. (2007) and a detailed explanation can be found in Appendix B.

[2] We should view our economy as one in which residential assets are perfectly liquid and there are perfect credit markets. Under these assumptions, the market allocation is invariant to the existence (or not) of a rental market for residential assets. Moreover, the shadow price of owner occupied housing services is equal to the rental price of housing. See, for further details, Davis and Heathcote (2005) or Díaz and Luengo-Prado (2010).

Table 1
Aggregate targets.

The benchmark economy		
Param.	Target	Value
β	Mean of $q_e\, K_e/Y_m$ in 1970–2007	0.9536
σ		1.0000
γ	Mean of $q_d\, K_d/Y_m$ in 1970–2007	0.2550
ψ	Mean of $r_h\, K_h/Y_m$ in 1970–2007	0.4327
ϕ	Value of H/N in 1970	4.1654
h_0	Mean of H/N in 1984–2007	3100
$\hbar$	Conesa et al. (2007)	5200
α_e	Mean of $r_e\, K_e/Y_m$ in 1970–2007	0.1238
α_s	Mean of $r_s\, K_s/Y_m$ in 1970–2007	0.1083
δ_e	Weighted average in EU KLEMS	0.1359
δ_s	Weighted average in EU KLEMS	0.0266
δ_d	Weighted average in EU KLEMS	0.2100
δ_h	Weighted average in EU KLEMS	0.0077

Notes: The targets are annual averages for the period 1973–2007.

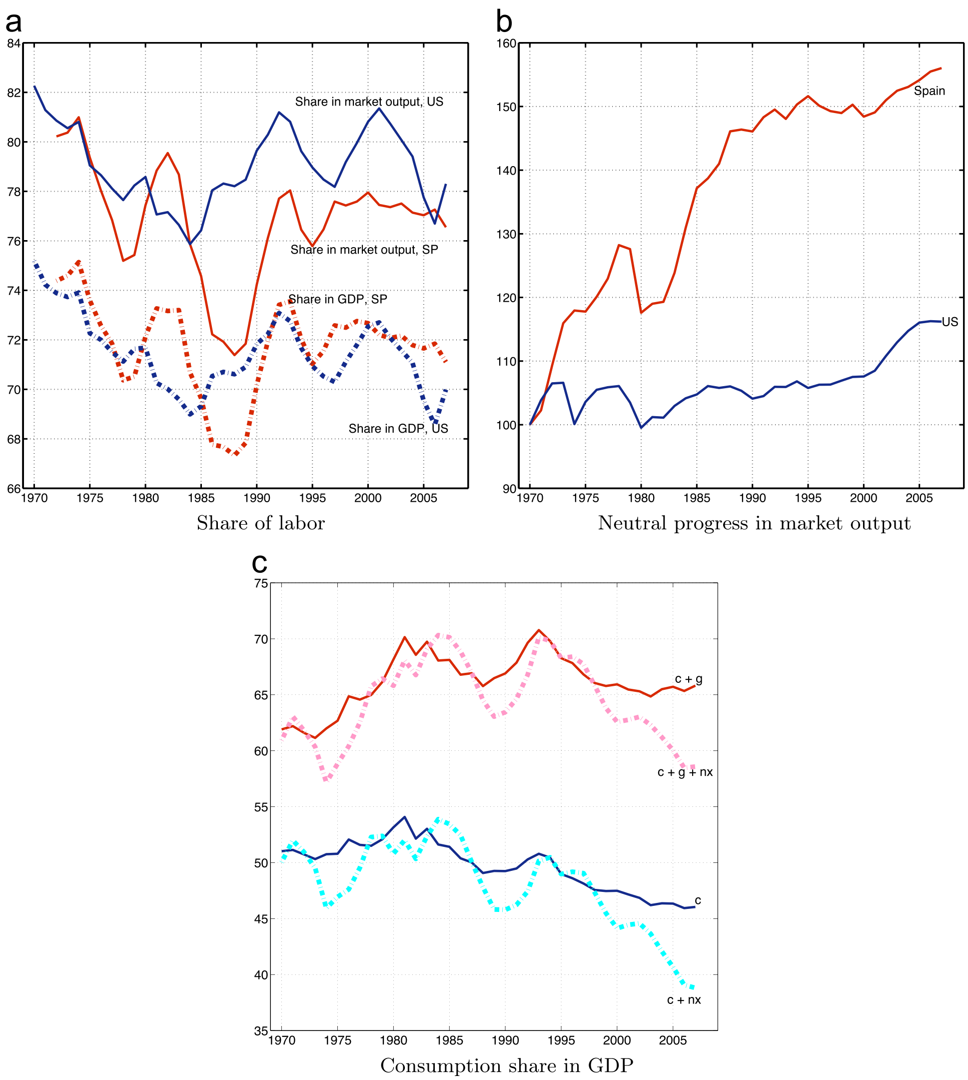

Fig. 2. Spain 1970–2007 (II).

5. The Spanish growth experience

Here we discuss the ability of our model economy to replicate the observed growth patterns in Spain. In Section 5.1 we present our benchmark economy where there are no subsidies. Next, we quantify in Section 5.2 the subsidy needed in the investment of structures and housing for our model economy to deliver the observed capital to GDP ratios. In Section 5.3 we study an alternative economy where there no subsidies and the price of structures and housing do not fluctuate over time. Finally, in Section 5.4 we further assume that ISTC in equipment in Spain is as high as in the US.

To simulate our economies we proceed in the following way: we feed into the model the initial stock of capital and the series of neutral technical progress, relative prices of capital, and the frictions considered. We keep the beliefs of the household unaltered but those that are part of the counterfactual exercise. In particular, in the economy with subsidies we assume that the subsidy at the steady state is such that the capital to output ratio from 2007 onwards is equal to that of 2007.

5.1. The economy without subsidies

Fig. 3 shows the results for our *benchmark* economy and compares the implied evolution of output, hours worked, capital-output ratios and non durable private consumption in the model and compare them with their appropriate counterpart in the data. Table 2 shows the growth rate of market output per worker in the data and the various economies considered for the entire period 1970–2007. We have divided the period 1970–2007 in three sub-periods corresponding to the three cycles that we observe in Spain during that entire period. We have used as trough points the two troughs observed in hours worked per working age population in the data: 1985 and 1995. The first cycle ends in 1985. It started before 1970. The second cycle starts in 1985 and ends in 1995. The last one started in 1996 and has not finished yet. Table 2 shows the decomposition of the growth rate of market output in its components, as shown in expression (3.2). Table 3 decomposes the growth rate of GDP on the contribution of market output and the services of housing. Table 4 shows the decomposition of TFP in market output according to expression (3.6), whereas Table 5 shows the decomposition of TFP in GDP; as shown in (3.15).

5.1.1. The period 1996–2007

Fig. 3(a) shows the evolution of GDP in the data (red line) and our benchmark economy (dash dotted dark blue line). Our benchmark economy cannot reproduce the observed growth patterns of Spain. In particular, the economy fails to replicate the growth pattern observed during the last period 1996–2007. We are going to focus our attention now to this period because it corresponds to the last (and longest) business cycle in Spain during the entire period 1970–2007. In the data, the average growth rate of GDP per worker was 2.74 percent, whereas the model economy delivers -0.52 percent. This negative growth rate is entirely due to the evolution of market output in the model, which falls at the rate -0.63 percent, whereas it grew at the rate 2.68 percent in the data. The difference between market output in the model and the data is mostly due to the behavior of hours worked, as shown in Table 2. In the data, 1.53 percentage points of the growth in market output are due to the increase in hours. In the model, hours worked have a negative contribution, -1.68 percent. The contribution of capital, 0.23 percent, is similar to the data, 0.17 percent. The fall in hours can be seen in Fig. 3(b). Fig. 3(d)–(f) shows that the model cannot account for the composition of capital observed in the data. The model economy, however, delivers the upward trend in the structures to GDP ratio, as observed in the data. On the contrary, it cannot reproduce the observed average housing to GDP ratio, although model and data have similar fluctuations.

Our hypothesis is that hours worked are low because TFP is low. Table 4 shows TFP of market output. During the period 1996–2007, the average growth rate in the data was 0.67 percent, whereas the model economy delivers 0.59 percent. The small difference is entirely due to the fact that the model economy cannot deliver the capital composition observed in the data. Thus, an artificial economy where TFP growth in market output is very similar to that observed in the data cannot reproduce the growth patterns of the Spanish economy. In the model economy the economy is stagnant during this period 1996–2007, period in which the Spanish economy was booming. Measured TFP in GDP in the model economy, however, is lower than its counterpart in the data. This is so because the measurement of TFP in GDP is affected by the composition of capital, $\mathcal{K}_m/\mathcal{K}$, and the ratio of labor to (detrended) capital, $H/\tilde{\mathcal{K}}$, as shown in expression (3.15). During that period the weight of business capital in the aggregate stock (measured in units of final good), $\mathcal{K}_m/\mathcal{K}$, is falling and the ratio of hours to private capital, $H/\tilde{\mathcal{K}}$, is also falling. The contribution of both factors is -0.58 percent, which almost offsets TFP in market output.

Notice, though, that the economy grows in the balanced growth path because we have assumed that after 2007 neutral progress grows at the average rate of the entire period 1970–2007 and that the price of structures and housing remain constant.

5.1.2. The period 1970–1995

Our model economy overestimates the growth experienced in Spain prior to 1986. This is due to the behavior of capital and hours worked. Tables 2 and 3 show the growth rate of market output and GDP for the period 1970–1985. They were, respectively, 1.07 and 0.97 percent. Our benchmark model delivers 1.82 and 1.86 percent. The bulk of the difference comes from the different contribution of capital and labor in market output. In the data, capital composition in market output

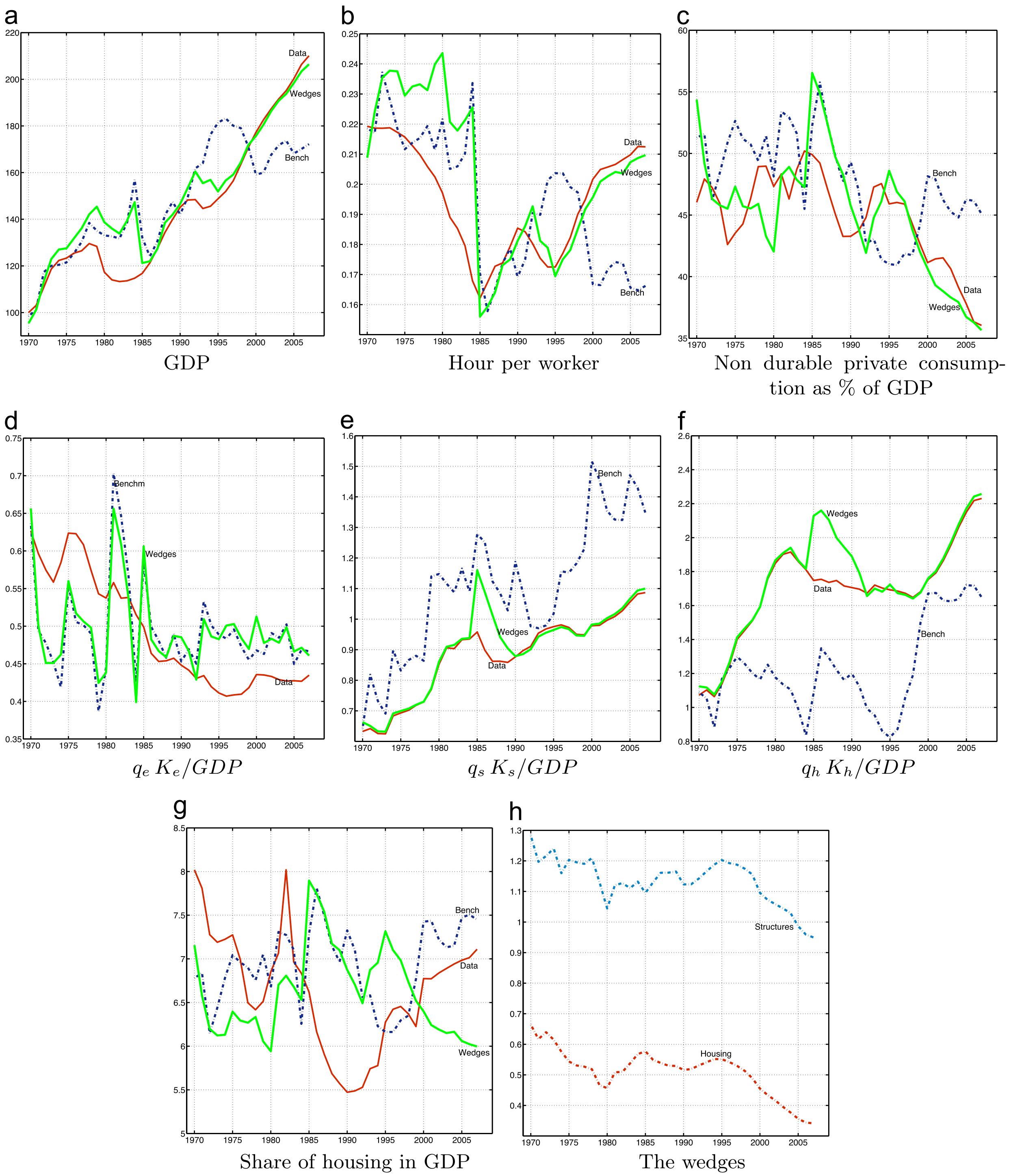

Fig. 3. The benchmark economy. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

contributes 0.11 percent to market output growth, whereas in the model this contribution rises to 0.53 percent. This is due to the fact that the model economy invests less in structures than the data. The rest of the difference comes from the behavior in hours. In the data, as well as in the benchmark economy, hours have a negative contribution, more so in the data. This is due to the fact that agents in the model work more before 1984 since they are aware that after 1984 the workweek is not flexible. As a consequence, they prefer to work now and save for the future. This explains the abrupt fall of hours worked in 1984. Interestingly, the model delivers a number of hours very close to that observed in the data in that year.

The model cannot replicate either the growth of GDP for the period 1986–1995. This is so because agents in the model work much more than in the data, since they know that they will not want to work as much in the next period 1996–2007. It is interesting to note that, although the model cannot replicate most of the patterns of the data, TFP is very close to its counterpart in the data, as shown in Tables 4 and 5. This implies that the model fails to deliver the observed growth experience of Spain because it fails to capture the observed patterns of capital accumulation and hours worked.

5.2. The role of subsidies

Now we turn to an economy where we assume that investment in housing and structures receive a subsidy (tax) so that the model economy delivers the housing stock (structures) to market output ratio observed in the data. To obtain this subsidy (tax) we assume that there are two wedges in the FOCs of structures and housing. There is a problem with this procedure around 1984. Due to the institutional change, hours worked fall abruptly in 1984. As a result, agents would like to undertake negative investment in structures and housing to smooth consumption. Thus, investment is zero so that the model economy cannot reproduce the capital to output ratio observed in the data during some periods.

The results of this economy are shown in Fig. 3. The economy is called *Wedges* and is the bright green solid line. A first inspection of the results shows that this economy performs fairly well in spite of the fact that it cannot replicate the capital to GDP ratios for structures and housing for the period 1984–1990. As we have explained, this is due to the labor market reform of 1984. The institutional change implies a fixed workweek. Agents respond to this change by participating less in the labor market and reducing investment to smooth consumption. Aside from the period 1984–1990, the capital to output ratio for structures and housing is the one observed in the data. The wedge needed for the model to deliver the ratios observed in the data are shown in Fig. 3(h). The mean wedge for structures is 1.1348, which implies a tax of 13.48 percent on the price of structures. On the contrary, the mean wedge for housing is 0.5106, which implies a mean subsidy of 48.94 percent in the price of housing. We should notice that both wedges decrease over time. This is due to the fact that the prices of both structures and housing increase over time. Thus, the model needs a larger subsidy (or lower tax) in order to replicate the data. Before discussing whether the magnitude of these wedges is reasonable we turn to study the evolution of this economy over time. Fig. 3(a) and (b) shows the implied level of GDP and hours worked in this economy. Notice that the evolution of GDP in the model tracks very closely that of the data after 1985. This is due to the fact that the model is able to replicate the behavior of hours worked. The model replicates fairly well also the dynamics of consumption, as shown in Fig. 3(c). Housing rents as a fraction of GDP are shown in Fig. 3(g). The model does not capture the fluctuations in this statistics, but it matches the observed ratio. In the data, the average of housing rents are 7.11 percent of GDP for the entire period 1970–2007. In the benchmark model economy this ratio is 7.45 percent, whereas the *Wedges* economy delivers 7.09 percent. Notice that the evolution of the stock of equipment is not much affected by the existence of wedges, as shown in Fig. 3(d). An inspection to Tables 2 to 5 shows that the economy reproduces very well the observed growth patterns of the Spanish economy for the periods considered. In particular, Tables 4 and 5 show that TFP statistics are not very much affected by the wedge and that they match reasonably well their counterparts in the data. That is, in order to understand the growth patterns of Spain, given the observed TFP, we need to take into account that investment in housing is heavily subsidized. In other words, the investment rate is inefficiently high.

The lesson we extract from comparing this economy with our benchmark economy is that the growth observed in Spain during the last period 1996–2007 was due to market distortions that, in spite of low TFP, increased the return to housing so much that the economy invested a lot in residential stock. This high return of housing rises demand and the cost of leisure so that agents are willing to work more. This result is related to Fisher (2007), who shows that household capital (i.e., housing) rises labor productivity in the business cycle frequency. There is much anecdotal evidence that suggests that investment in residential structures is heavily subsidized in Spain although there are few attempts to measure the macroeconomic impact of those subsidies. García-Montalvo (2012), for instance, estimates that the fiscal benefits associated to the purchase of the first residence amount to a subsidy of about 10 to 20 percent of the housing price. According to García-Montalvo (2012), these benefits cost about 1 percent of GDP during the 1990s and 2000s. In our *Wedges* economy the subsidy to purchases of residential stock amounts, on average, to 3.51 percent of annual GDP. The average for the last period 1990–2007 is 3.82 percent, a number of the same magnitude that the one estimated by García-Montalvo (2012). The wedge on structures that we have estimated amounts roughly to a tax of 14.38 percent. The implied tax revenues amount to 0.86 percent of GDP annually. We do not have any estimate for this wedge in the data. Nevertheless, Gravelle (2011) estimates the effective tax rates on business equipment and structures for different types of investment goods in the US economy. These effective tax rates measure the estimated share of the return that is collected in taxes. For instance, the effective tax rate on communications equipment is 19 percent, whereas the return of industrial structures is effectively taxed at 37 percent. The differential tax paid by structures is about 15 percent, a number close to our wedge. A similar study for Spain would be needed to go beyond our aggregate estimates.

In the following two Sections we turn to study three counterfactual economies to assess quantitatively the cost of housing and structures price fluctuations as well as that of low Investment Specific Technical Change in equipment.

Table 2
Average growth rate of market output and its decomposition.

	Data	Bench.	Wedges	H	H&S	ISTC
1970–2007						
y_m	2.00	1.46	2.08	1.61	1.63	1.97
Z	1.52	1.52	1.52	1.52	1.52	1.52
q_e	0.52	0.52	0.52	0.52	0.52	0.74
q_s	0.00	0.00	0.00	0.00	0.00	0.00
$q_e\ k_e/y_m$	−0.16	−0.13	−0.16	−0.15	−0.15	−0.11
$q_s\ k_s/y_m$	0.20	0.28	0.18	0.27	0.23	0.21
h	−0.08	−0.72	0.01	−0.55	−0.49	−0.39
1970–1985						
y_m	1.07	1.82	1.46	1.32	1.26	1.58
Z	2.52	2.52	2.52	2.52	2.52	2.52
q_e	0.33	0.33	0.33	0.33	0.33	0.61
q_s	0.02	0.02	0.02	0.02	0.00	0.00
$q_e\ k_e/y_m$	−0.24	−0.08	−0.07	−0.04	−0.04	−0.28
$q_s\ k_s/y_m$	0.35	0.61	0.50	0.65	0.76	0.70
h	−1.87	−1.55	−1.80	−2.11	−2.25	−1.92
1986–1995						
y_m	2.05	4.06	2.27	3.51	3.41	3.30
Z	1.22	1.22	1.22	1.22	1.22	1.22
q_e	0.53	0.53	0.53	0.53	0.53	0.77
q_s	0.08	0.08	0.08	0.08	0.00	0.00
$q_e\ k_e/y_m$	−0.19	−0.06	−0.01	−0.03	0.01	−0.17
$q_s\ k_s/y_m$	0.12	−0.32	−0.18	−0.29	−0.32	−0.27
h	0.30	2.58	0.62	1.98	1.96	1.73
1996–2007						
y_m	2.68	−0.63	2.43	0.59	1.10	1.93
Z	0.43	0.43	0.43	0.43	0.43	0.43
q_e	0.63	0.63	0.63	0.63	0.63	0.75
q_s	−0.16	−0.16	−0.16	−0.16	0.00	0.00
$q_e\ k_e/y_m$	0.10	−0.03	−0.13	−0.04	−0.09	0.23
$q_s\ k_s/y_m$	0.13	0.20	0.13	0.22	−0.08	−0.12
h	1.53	−1.68	1.52	−0.48	0.21	0.63
BGP						
y_m	–	2.05	2.05	2.05	2.05	2.27
$\frac{yModel_{m\ 2007}}{y^{Data}_{m\ 2007}}$	1.00	0.82	0.99	0.84	0.86	0.96

Notes: **BGP** refers to the growth rate at the balanced growth path.

Table 3
Average growth rate of GDP and its decomposition.

	Data	Bench.	Wedges	H	H&S	ISTC
1970–2007						
GDP	1.97	1.48	2.05	1.61	1.63	1.96
$r_h\ k_h$	−0.03	0.02	−0.03	0.01	0.00	−0.01
y_m	2.00	1.46	2.08	1.61	1.63	1.97
1970–1985						
GDP	0.97	1.86	1.51	1.40	1.35	1.64
$r_h\ k_h$	−0.09	0.03	0.05	0.08	0.09	0.06
y_m	1.07	1.82	1.46	1.32	1.26	1.58
1986–1995						
GDP	2.07	3.88	2.22	3.36	3.26	3.17
$r_h\ k_h$	0.01	−0.18	−0.05	−0.14	−0.14	−0.13
y_m	2.05	4.06	2.27	3.51	3.41	3.30
1996–2007						
GDP	2.74	−0.52	2.33	0.62	1.08	1.88
$r_h\ k_h$	0.05	0.12	−0.10	0.03	−0.01	−0.04
y_m	2.68	−0.63	2.43	0.59	1.10	1.93

Table 4
Average growth rate of TFP in market output and its decomposition.

	Data	Bench.	Wedges	H	H&S	ISTC
1970–2007						
A_m	1.48	1.46	1.49	1.46	1.48	1.67
Z	1.16	1.16	1.16	1.16	1.16	1.16
q_e	0.40	0.40	0.40	0.40	0.40	0.57
q_s	0.00	0.00	0.00	0.00	0.00	0.00
k comp.	−0.08	−0.10	−0.07	−0.11	−0.08	−0.06
1970–1985						
A_m	2.10	2.06	2.10	2.06	2.01	2.17
Z	1.93	1.93	1.93	1.93	1.93	1.93
q_e	0.25	0.25	0.25	0.25	0.25	0.47
q_s	0.02	0.02	0.02	0.02	0.00	0.00
k comp.	−0.11	−0.15	−0.11	−0.15	−0.17	−0.23
1986–1995						
A_m	1.30	1.50	1.46	1.50	1.48	1.58
Z	0.93	0.93	0.93	0.93	0.93	0.93
q_e	0.40	0.40	0.40	0.40	0.40	0.59
q_s	0.06	0.06	0.06	0.06	0.00	0.00
k comp.	−0.10	0.10	0.06	0.10	0.14	0.05
1996–2007						
A_m	0.67	0.59	0.60	0.58	0.81	1.04
Z	0.33	0.33	0.33	0.33	0.33	0.33
q_e	0.48	0.48	0.48	0.48	0.48	0.57
q_s	−0.12	−0.12	−0.12	−0.12	0.00	0.00
k comp.	−0.02	−0.10	−0.09	−0.11	0.00	0.13
BGP						
A_m	–	1.57	1.57	1.57	1.57	1.74

Notes: **BGP** refers to the growth rate at the balanced growth path.

Table 5
Average growth rate of TFP in GDP and its decomposition.

	Data	Bench.	Wedges	H	H&S	ISTC
1970–2007						
A	1.13	1.30	1.12	1.53	1.57	1.76
$r_h k_h$	−0.01	0.02	−0.03	0.01	0.00	−0.01
$A_m^{1-\varphi_h}$	1.38	1.36	1.39	1.36	1.38	1.56
$\mathcal{K}_m/\mathcal{K}$	−0.17	−0.02	−0.17	0.18	0.18	0.19
$H/\tilde{\mathcal{K}}$	− 0.07	−0.07	−0.06	−0.02	0.00	0.00
1970–1985						
A	1.65	2.08	1.57	2.26	2.24	2.38
$r_h k_h$	0.06	0.03	0.05	0.08	0.09	0.06
$A_m^{1-\varphi_h}$	1.95	1.92	1.97	1.92	1.88	2.02
$\mathcal{K}_m/\mathcal{K}$	−0.25	0.23	−0.25	0.35	0.38	0.37
$H/\tilde{\mathcal{K}}$	−0.11	−0.11	−0.18	−0.10	−0.12	−0.08
1986–1995						
A	1.30	1.72	1.61	1.64	1.58	1.64
$r_h k_h$	−0.01	−0.18	−0.05	−0.14	−0.14	−0.13
$A_m^{1-\varphi_h}$	1.21	1.39	1.32	1.40	1.37	1.47
$\mathcal{K}_m/\mathcal{K}$	0.07	0.31	0.19	0.23	0.19	0.15
$H/\tilde{\mathcal{K}}$	0.00	0.18	0.09	0.15	0.15	0.14
1996–2007						
A	0.23	0.09	0.12	0.56	0.84	1.11
$r_h k_h$	−0.08	0.12	−0.10	0.03	−0.01	−0.04
$A_m^{1-\varphi_h}$	0.63	0.55	0.56	0.54	0.75	0.97
$\mathcal{K}_m/\mathcal{K}$	−0.21	−0.42	−0.26	0.05	0.05	0.14
$H/\tilde{\mathcal{K}}$	−0.10	−0.16	−0.08	−0.06	0.05	0.04
BGP						
A	–	1.46	1.46	1.46	1.46	1.62

Notes: **BGP** refers to the growth rate at the balanced growth path.

5.3. The cost of price booms

In this section we present two counterfactual economies in which there are no wedges. In the first one, we assume that there were no fluctuations in the housing price during the entire period 1970–2007. We take the relative price to be equal to the average of the period. This economy is labeled *H*. In the second economy we also assume that the price of structures did not change and its value is set to the average of the period. This economy is labeled *H* & *S*. Fig. 4 shows the evolution of GDP, hours worked, consumption and the capital-GDP ratios for these two economies.

The first thing that we should notice is the growth rate of GDP at the balanced growth path of these two economies is the same that the growth rate of the benchmark and the *Wedges* economy, since we have assumed that in the long run the prices of structures and housing do not change. The difference across economies arises from differences in prices during the period 1970–2007. Let us start with the *H* economy, where the housing price is constant but the price of structures fluctuates. A visual inspection of Fig. 4 shows that this economy is very similar to our benchmark economy, but for the last period 1996–2007. The *H* economy delivers a growth rate of GDP equal to 0.62, whereas the benchmark economy delivers -0.52 for the period 1996–2007. Thus, the cost of the housing price boom is 1 percentage point of GDP annual growth. This cost is due to a lower growth rate of market output (-0.63 in the benchmark economy versus 0.59 percent in the *H* economy). This lower growth of market output during the housing boom is due to the behavior of hours worked. In the benchmark economy hours worked fell at a rate equal to 1.68 percent whereas, without housing price boom, the fall would have been -0.48 percent. Table 4 shows that the housing price boom does not affect TFP in market output (0.58 in the *H* economy versus 0.59 in the benchmark economy), but affects very much the measurement of TFP in GDP. TFP in GDP is 0.56 in the *H* economy, whereas it is 0.09 percent in the benchmark economy. The difference is due to the fact that the total amount of capital, measured in units of final good, is smaller in the *H* economy than in the benchmark economy. As a consequence, TFP is higher in the *H* economy. Summarizing, in absence of a house price boom, hours worked would have

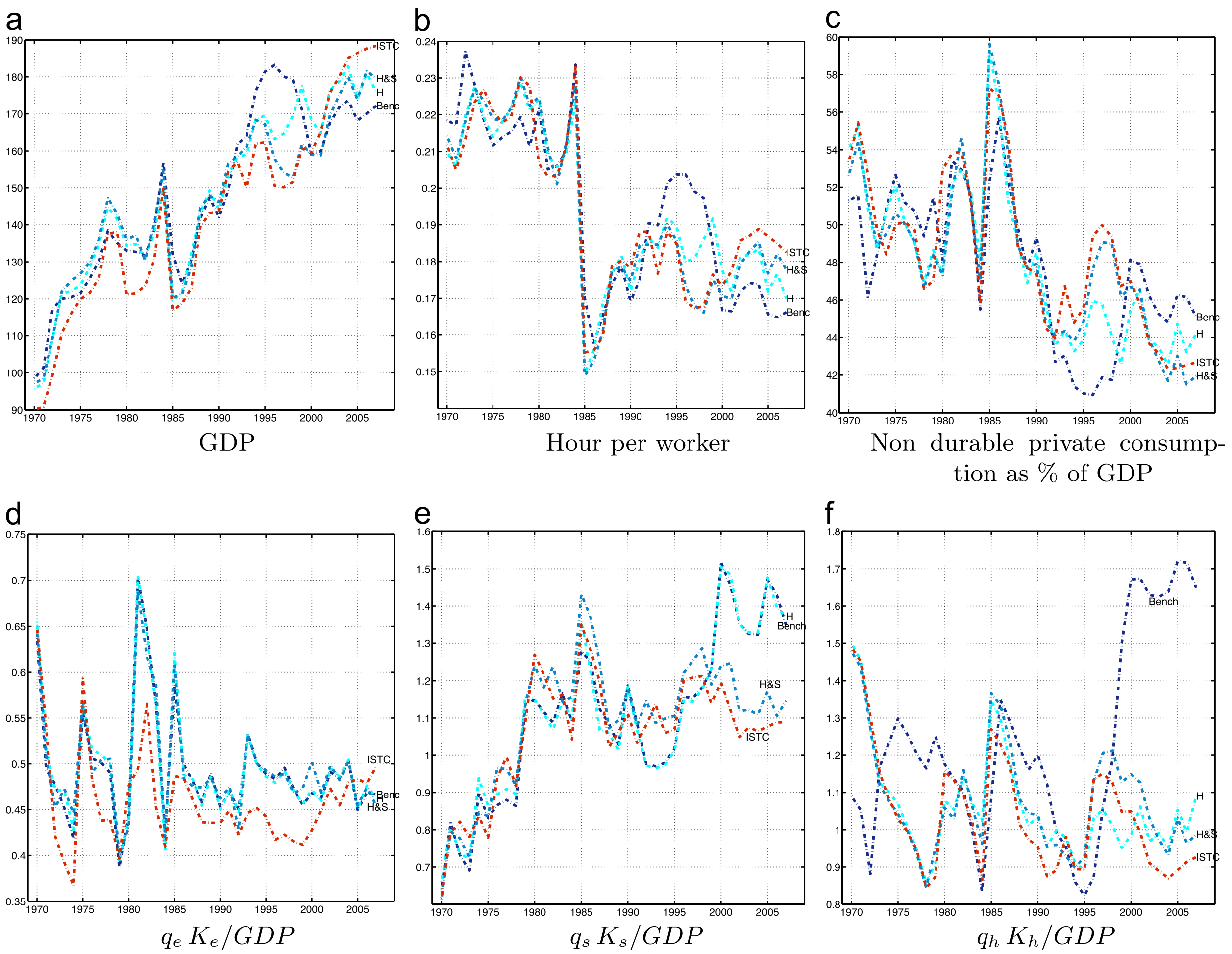

Fig. 4. The effect of price booms and the role of ISTC. 'H' refers to 'No house price boom', 'H&S' refers to 'No structures and house price boom', and 'ISTC' refers to 'US ISTC' economy.

grown one percentage point faster every year. This higher growth would have implied a growth rate of GDP and its TFP half percentage point higher, but would have left TFP in market output unaltered.

Now we can turn to study the *H* & *S* economy, where the price of structures is also constant. Again, the most striking differences between this economy and the benchmark economy occur during the last period 1996–2007, period in which the structures price rose significantly. Comparing this economy with the benchmark economy and the *H* economy, we can see that the GDP growth rate is even higher, 1.08 percent, versus 0.62 percent in the *H* economy. This difference is due to the effect on hours worked (now they grow at the rate 0.21) and the increase in TFP in market output (its growth rate is 0.81 percent versus 0.59 percent in the *H* economy). As a result, TFP in GDP grows at the rate 0.84 percent annually. Summarizing, eliminating fluctuations in the price of structures has a direct effect on TFP in market output (notice in Fig. 4(e) that the ratio of structures to GDP is now lower) and also in hours, whose marginal product rises even further with respect to the *H* economy.

5.4. The effect of ISTC

In this economy we further assume that the relative price of equipment falls at the same rate that the relative price of business equipment in the US. We saw in Section 4.2 that the relative price of equipment has fallen at the annual rate 3.37 percent in Spain, as opposed to 4.82 in the US economy. Here we want to assess the quantitative gain of a faster pace of Investment Technical Change. We have labeled this economy the *ISTC* economy and Fig. 4 shows the evolution of its main aggregates. The growth rate of output at the balanced growth path is higher, 2.27 percent versus 2.05 in the benchmark economy. The difference is entirely due to the higher ISTC in this new economy. Interestingly, most aggregates are very similar to those of the benchmark economy during the period 1970–2007. There are some minor differences during the last period 1996–2007. In the *ISTC* economy GDP grows at the rate 1.88 percent. Thus, higher ISTC adds one percentage point to GDP growth with respect to the *H&S* economy. This larger growth rate is due to higher TFP in market output and a higher growth rate in hours worked. In spite of high ISTC, the level of output per worker in 2007 in this economy is the same that in the data. This is due to the fact that hours worked are very low. Output per worker in the *ISTC* economy is below its counterpart in the benchmark economy until the late 1990s, moment after which the *ISTC* economy starts growing at a higher rate and reaches its balanced growth path with a higher growth rate, 2.27 percent versus 2.05 percent in the benchmark economy. Table 5 shows the TFP decomposition in this case. The main lesson that we extract from this counterfactual economy is that the key factor determining TFP is Investment Specific Technical Change. In an economy with high ISTC, as the US, TFP is higher. The second lesson is that in this economy, hours worked remain too low. Thus, rising ISTC will not bring an increase in hours worked and output. We need to take into account that we have calibrated the utility function to match the observed mean of hours worked, and average hours worked in Spain are low. In order to assess the impact of a change in ISTC in hours worked we would need to study and model explicitly the policies that affect labor supply and demand in Spain, aside from a fixed workweek.

5.5. International borrowing and lending

In our previous exercises we have assumed that Spain is a closed economy, which is clearly not. Here we want to assess the bias in which we incur by assuming a closed economy. Fig. 2(c) shows net exports in Spain as percentage of output. They are negatively correlated with output and their fluctuations have increased after Spain adopted the euro. In particular, we have been running a deficit since mid 1990s. Here we conduct the following exercise. We take as given the trade balance as percentage of output and set the time series for the interest rate on the internationally traded bond so that, in fact, our benchmark economy has a trade balance of the same magnitude as in the data. In this new economy the trade balance is no longer imputed to private consumption. As for the subsidy, we proceed as in our *Wedges* economy and we keep all the assumptions about the relative price of capital goods and government expenditures along the balanced growth path. We need to add the beliefs of the dynasty about the future trade balance and the volume of international borrowing and lending. In an exercise close to that conducted by Kehoe et al. (2013), we assume that there is a gradual rebalancing of the current account until the economy reaches its balanced growth path, which happens in 2018. During the transition, the current account, as percentage of output, mirrors backwards (symmetrically), the size of the current account in Spain from 2007 to 1997, year in which there was a surplus.

Fig. 5 shows the evolution of output, hours worked and private consumption plus the trade balance as percentage of output. We have not plotted the capital to GDP ratios since they are essentially the same that in the *Wedges* economy. The key difference between the closed and the open economy is that in this case, agents do not work in the open economy as much as in the closed economy since they can import final good from abroad. In spite of that difference, we think that our closed economy is a good approximation of this open economy. Fig. 5(c) shows the interest rate of the internationally traded bond along the period 1970–2007. On average, its return is about 6 percent, which is a bit high, specially during the period 1996–2007. Notice that we have abstracted from distortionary taxation that lowers the after tax return of capital. The important thing, though, is that the implied interest rate has a downward trend, which is consistent with the evidence in Spain.

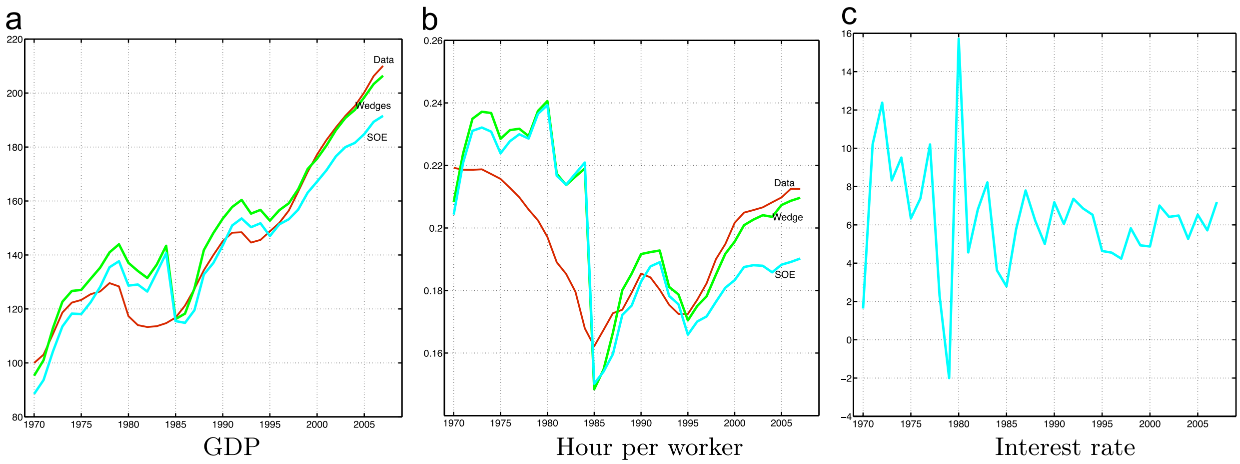

Fig. 5. The small open economy.

6. Final comments

Spain is an economy with low Total Factor Productivity which is able to sustain high GDP growth. This was particularly striking during the last expansive period of the Spanish economy, 1996–2007, where TFP grew at 0.23 percent annually, whereas the growth rate of GDP per worker was 2.74 percent. To study this puzzling behavior of the Spanish economy we have built a model economy along the lines of Greenwood et al. (1997) and Davis and Heathcote (2005). Market output is produced with equipment and non residential structures. Agents purchase residential stock to produce housing services. Our economy can be understood as one in which financial markets are perfect and there are no differences in human capital across agents. In this case, in absence of distortionary taxation, the market allocation is neither affected by the distribution of wealth nor the absence of a rental market of housing, (see, for instance, Álvarez-Peláez and Díaz, 2005; Díaz and Luengo-Prado, 2008). We have abstracted from any heterogeneity across households to concentrate in the main sources of growth of the economy. In our theory we take as exogenously given the fact that the relative prices of capital goods change over time. In particular, we do not have a theory for the behavior of residential structures (see, for instance, for different theories using search or financial market frirctions Díaz and Jerez, 2013; Franjo, 2014). We apply the methodology of Kehoe and Prescott (2002) to study the growth patterns of Spain during the period 1970–2007.

The source of low TFP is a combination of low ISTC in equipment, the upsurge in the relative price of residential and non residential investment and the importance of residential structures, which comprise more than two thirds of total capital in Spain. The main lesson we learn in this paper is that a neoclassical model economy cannot reconcile the observed low TFP growth rate and the observed GDP growth rate in Spain in absence of market distortions that rise the return to residential capital. Given the evolution of the price of housing, a neoclassical model economy with perfect capital markets, calibrated in a reasonable way to reproduce the main features of the Spanish economy, does not generate enough housing demand to accumulate so much residential capital as we see in the data. We lend support to the conventional wisdom that Spanish growth is due to factor accumulation, not TFP growth, but we show that in absence of TFP growth we cannot rationalize such a high GDP growth rate. In other words, given the observed rate of TFP, the investment rate of the model economy is much lower. That is, the investment rate observed in Spain during the period 1970–2007 is inefficiently high. We also give support to the idea that subsidies to the purchase of residential stock are at the heart of the high accumulation of residential structures. We introduce a wedge as a subsidy to the purchase of residential structures. The estimated wedge is about 50 percent of the price of residential structures. García-Montalvo (2012) estimates that the subsidy to the purchase of the first home is about 10 to 20 percent of the value of the house. The total cost of this subsidy amounts to 3.5 percent of GDP in our model economy. García-Montalvo (2012) estimates a total cost of 1 percent of GDP since 1990. Our estimates are of the same order of magnitude. We also need to take into account that we are abstracting from distortionary taxation, which may affect our estimate of the subsidy. It is interesting to note the connection between investment in residential stock and hours worked. By subsidizing the purchase of houses we are rising the marginal utility of non durable consumption, which lowers the cost of leisure. As a result, the supply of hours increases and hours worked increase, too.

We have run a series of counterfactual economies to have a sense of which type of policies may help to boost TFP and, therefore, GDP growth. We find that house price booms (in absence of subsidies) lower GDP growth through hours worked and lower accumulation of residential capital, and have a mild effect on TFP. Price booms in business structures do have an extra effect on TFP, since it amounts to a fall in Investment Specific Technical Change. Adding higher ISTC in business equipment rises TFP and output, but does not affect much hours worked. This is so because we have calibrated our model economy to reproduce the fact that average hours worked per working age person in Spain is low. Structural unemployment is very high in Spain, and tackling this issue is out of the scope of this paper. Nevertheless, any policy aiming to rise average hours worked will have a level effect on GDP, not a growth rate effect, in the long run. The question that remains is what features of the Spanish economy explain the fact that ISTC growth is lower in Spain than in the US economy.

Why is ISTC low in Spain? Some researchers, as Mas and Robledo (2010), point to sectoral composition, given the weight of sectors that are intensive in structures, as tourism, in total Value Added. Other researchers, as Pagano and Schivardi (2003) point to firms size distribution, which is very skewed in Spain. Smaller firms have lower productivity than larger firms. Other authors, as Alonso-Borrego (2010), argue that lack of competition explains that firms do not invest much in R&D, compared to other countries. Moreover, reallocation of resources across firms is very low in Spain, consistently with the evidence reported by Bartelsman et al. (2013) for a cross-section of countries. This suggests that lack of competition may be responsible of misallocation of resources, which might be at the heart of low ISTC in Spain.

Finally, perhaps the strongest simplification we have adopted in this paper is the fact that we have assumed that taxes are not distortionary. This affects our estimate of the subsidy to residential structures and, particularly, the behavior of hours worked. We have also stopped our analysis in 2007, since we do not have a theory for the Great Recession. We leave these issues for further research.

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Appendix A. The data

In this section we describe the data used and the construction of the stock of capital and its implicit price deflator.

A.1. Data sources

We use data collected by the Ministry of Public Finance and Administration, the *Macroeconomic Data Base of Spain* (BDMACRO hereafter), which comprises the main macro aggregates of the Spanish economy starting form 1954 at the annual frequency. This database, though, does not disaggregate investment by type, although it decomposes public expenditures in consumption and investment. It does not contain information about expenditures in durable consumption goods, since it only provides the private consumption aggregate. The advantage of this database, though, is that it links all the historical macroeconomic data collected by the *Instituto Nacional de Estadística*, (INE hereafter), the institution that constructs the Spanish National Accounts. The *Instituto Valenciano de Investigaciones Económicas* (IVIE hereafter) collects detailed information about investment disaggregated by type and ownership since 1954. It also calculates capital stocks by type and ownership using the perpetual inventory method. The main investment aggregates are consistent with those reported by BDMACRO and, therefore, the INE. The IVIE, though, does neither use investment prices adjusted by quality nor it uses a geometric depreciation rate when it calculates the capital stocks for the period 1954–1969. It does so for the data constructed for the EU KLEMS project.[3] The price of investment in structures does not include the value of land. This is the common practice in National Accounts since changes in the price of land produce transfers of resources across agents but do not affect productivity of factors. The disadvantage is that the data in EU KLEMS starts in 1970. The EU KLEMS project also provides information about the components of National Income. The series of expenditures in durable consumption goods is taken from Márquez (2004), who update the original series constructed by Estrada and Sebastián (1993), and the INE.

A.2. The relative price of investment goods and the stock of capital

We distinguish four types of private capital. Equipment, structures, housing and consumer durable goods. The data for the three first categories is taken from EU KLEMS. This database organizes capital and investment in eight categories. Two of them are *Residential investment* and *Other constructions*. The other categories correspond to various types of business equipment, including software. EU KLEMS also provides deflators for the eight categories and calculates the capital stock using a perpetual inventory method. We create three composite categories: *Structures*, *Equipment*, and *Housing*. The category Structures corresponds to *Other constructions*, Housing corresponds to *Residential investment* whereas Equipment comprises the other six categories.

To construct the composite *Equipment*, we take the implicit price deflator of each type of investment good, $D^j_{i\,t}$, from EU KLEMS. We construct the implicit price deflator of non durable goods and services, $D_{ndc\,t}$, using the data of Estrada and Sebastián (1993) and Márquez (2004). We define the relative price of the investment good i in category e (equipment) as

[3] In http://www.euklems.net/index.html

$q^e_{i\,t} = D^e_{i\,t}/D_{ndc\,t}$. We construct a constant-price measure of investment in equipment as $X_{et} = \sum_i q^e_{i\,0} X^e_{i\,t}$. We take as base year 1996. Thus, the implicit price deflator of equipment is

$$q_{et} = \frac{\sum_i q^e_{i\,t} X^e_{i\,t}}{X_{et}}. \tag{A.1}$$

Next, we calculate the real stock so that

$$K_{et} = \frac{\sum_i q^e_{i\,t} K^e_{i\,t}}{q_{et}}, \tag{A.2}$$

where $K^e_{i\,t}$ is the real capital stock calculated by EU KLEMS for each type of investment good. Using a perpetual inventory method backwards we compute the average depreciation rate for the period 1970–2008, which is $\delta_e = 0.1361$.

EU KLEMS constructs the stocks of structures and housing. We have calculated their relative price using the deflator of non durable goods and services. Their average depreciation rates are, respectively, $\delta_s = 0.0277$ and $\delta_h = 0.0077$. Next, we construct the stock of durable goods. Prior to 1995, the Spanish National Accounts do not report disaggregated information on consumption expenditures. For the period 1964–1995, we use the data collected by Estrada and Sebastián (1993) and Márquez (2004), who also report the implicit price deflator for the disaggregated consumption expenditure components. Our definition of consumer durable goods is slightly different from that used by the aforementioned authors since we do not include private expenditures in schooling. We calculate the stock of consumer durable goods by applying a perpetual inventory method for the period 1964–2008, last year for which we have disaggregated consumption data. Let I_{dt} be the expenditure in durable goods in current euros at time t. We obtain its relative price, q_{dt}, by dividing its deflator by the implicit price deflator of non durable goods and services. We follow Puch and Licandro (1997) and assume that consumption durable goods have a depreciation rate of $\delta^d = 0.21$. Thus,

$$K_{d\,t+1} = \frac{I_{dt}}{q_{dt}} + (1-\delta_d)K_{dt}. \tag{A.3}$$

The initial stock is chosen so that the ratio of the stock to market output (in nominal terms) in the initial year is the same that in the last year of the sample, 27 percent. Over the period considered, the stock of durable goods amounts to 29 percent of measured GDP, on average, with a minimum of 27 percent in 2008 and a maximum of 36 percent in 1979.

A.3. US data

The data for the US economy is taken from the Bureau of Economic Analysis (National Income and Product Accounts and Fixed Asset Tables). The BEA constructs the stock of consumer durable goods. We use the series of relative prices of business equipment estimated by Rodríguez-López and Torres (2012), who update the original series of Cummins and Violante (2002). We re-estimate the stock of business equipment accordingly to this price and a perpetual inventory method so that the stock of business equipment is equal to the series provided by the BEA in units of non durable consumption goods and services. The aggregates are calculated in the same way that their counterparts for Spain. Data on hours worked and population are taken from the Bureau of Labor Statistics.

Appendix B. Numerical solution procedure

We follow the method employed by Conesa et al. (2007). We assume that the economy starts at some T_0 and converges to its balanced-growth path at some, large enough, T_1. We need to choose sequences, $\Omega = \{y_{mt}, h_t, c_t, \pi_t, (x_{jt}, k_{jt+1})\}_{t=T_0}^{T_1}$ that solve the system of equations formed by the FOCs of the household's problem, feasibility and the government's budget constraint. The algorithm involves making an initial guess at the variables, Ω^0, and updating the guess by $\Omega^{i+1} = \Omega^i - Df(\Omega^i)^{-1} f(\Omega^i)$, where $Df(\Omega^i)$ is the matrix of partial derivatives of $f(\Omega)$ evaluated at Ω^i. The system of equations does not have closed-form expressions for the partial derivatives needed to compute $Df(\Omega^i)$, and so the derivatives have to be evaluated numerically. A solution is obtained when the function, evaluated at the new iterate of Ω, has a maximum error less than some value ε, where ε is a small number. Although this method of solving a system of nonlinear equations can converge to a solution quickly, this method is not globally convergent and can become stuck away from a zero of $f(\Omega)$ or may not converge at all. The initial guess, Ω^0, is important.

To increase the probability of the algorithm converging to the correct answer, we solve a sequence of models, beginning with a simple version of the model, which we know how to solve, and progressing towards the model that we would like to solve. The first model we solve is the one in which Z_t, the relative price of capital goods, population, and available hours are constant and equal to their average values from 1973 to 2007. The solution to this problem is relatively easy to find. The next model takes Z_t, the relative price of capital goods, population, and available hours, to be convex combinations of the constant values used in the initial model and the actual values from the data. Let λ be the weight on the constant values, so that $(1-\lambda)$ is the weight on the values from the data. The algorithm requires repeatedly decrementing λ and solving the resulting model, each time using the solution to the model before it as the initial guess. The algorithm proceeds until it solves the case in which $\lambda = 0$, which corresponds to the model whose solution I desire. If the value of investment becomes negative in some period t, we replace the corresponding FOC associated to that investment by one where investment is set equal to zero.

To solve the model with wedges we add two more equations:

$$q_{jt}\, k_{jt} = \kappa_{jt}\, y_{mt}, \quad \text{for all } t, \tag{B.1}$$

where κ_{jt} is the capital to market output ratio for capital good j observed in the data, and j refers to structures and housing.

Appendix C. Supplementary data

Supplementary data associated with this paper can be found in the online version at http://dx.doi.org/10.1016/j.euroecorev.2015.11.009.

References

Alonso-Borrego, C., 2010. Firm behavior, market deregulation and productivity in Spain. Banco de España Working Papers 1035, Banco de España.

Álvarez-Peláez, M.J., Díaz, A., 2005. Minimum consumption, transitional dynamics and the wealth distribution. J. Monet. Econ. 52 (3), 633–667.

Bartelsman, E., Haltiwanger, J., Scarpetta, S., 2013. Cross-country differences in productivity: the role of allocation and selection. Am. Econ. Rev. 103 (1), 305–334.

Bentolila, S., Cahuc, P., Dolado, J.J., Barbanchon, T.L., 2012. Two tier labour markets in the great recession france versus Spain-super-. Econ. J. 122 (562), F155–F187.

Chen, K., İmrohoroğlu, A., İmrohoroğlu, S., 2006. The japanese saving rate. Am. Econ. Rev., 1850–1858.

Conesa, J.C., Kehoe, T.J., Ruhl, K.J., 2007. Modeling great depressions: the depression in Finland in the 1990s. Q. Rev. (November), 16–44.

Cooley, T.F., Prescott, E.C., 1995. Economic growth and business cycles. In: Cooley, T.F. (Ed.), Frontiers of Business Cycle Research, Princeton University Press, Princeton, pp. 1–38. Chapter 1.

Cummins, J.G., Violante, G.L., 2002. Investment-specific technical change in the US (1947–2000): measurement and macroeconomic consequences. Rev. Econ. Dyn. 5 (2), 243–284.

Davis, M.A., Heathcote, J., 2005. Housing and the business cycle. Int. Econ. Rev. 46 (3), 751–784.

Díaz, A., Jerez, B., 2013. House prices, sales, and time on the market: a search-theoretic framework. Int. Econ. Rev. 54, 837–872.

Díaz, A., Luengo-Prado, M.J., 2008. On the user cost and homeownership. Rev. Econ. Dyn. 11 (3), 584–613.

Díaz, A., Luengo-Prado, M.J., 2010. The wealth distribution with durable goods. Int. Econ. Rev. 51 (1), 143–170.

Estrada, A., Sebastián, M., 1993. Una serie de gasto en bienes de consumo duradero. Estudios Económicos, 9305. Banco de España.

Fisher, J.D., 2007. Why does household investment lead business investment over the business cycle? J. Polit. Econ. 115 (1), 141–168.

Franjo L., 2014. International interest rates and housing markets. Ècole Polytechnique Fèdèrale de Lausanne.

García-Montalvo, J., 2012. La desgravación a la compra de vivienda en españa: Una reconsideración. Economistas 30 (131), 173–180.

Gravelle, J.G., 2011. Reducing depreciation allowances to finance a lower corporate tax rate. Natl. Tax J. 64, 1039–1052.

Greenwood, J., Hercowitz, Z., Krusell, P., 1997. Long-run implications of investment-specific technological change. Am. Econ. Rev. 87 (3), 342–362.

Hayashi, F., Prescott, E.C., 2002. The 1990s in Japan: a lost decade. Rev. Econ. Dyn. 5 (1), 206–235.

Kehoe, T.J., Prescott, E.C., 2002. Great depressions of the twentieth century. Rev. Econ. Dyn. 5 (1), 1–18.

Kehoe, T.J., Ruhl, K.J., Steinberg, J.B., 2013. Global imbalances and structural change in the United States. NBER Working Papers 19339, National Bureau of Economic Research, Inc.

Márquez, E., 2004. Una propuesta para la elaboración de series de gasto en consumo por tipo de consumo para el caso español. Documentos de Trabajo Universidad Complutense de Madrid, 04–022.

Martínez, D., Rodríguez-López, J., Torres, J.L., 2008. The productivity paradox and the new economy: the Spanish case. J. Macroecon. 30 (4), 1569–1586.

Mas, M., Robledo, J.C., 2010. Productividad: una perspectiva internacional y sectorial. Number 2011100 in Books. Fundacion BBVA/BBVA Foundation.

O'Mahony, M., Timmer, M.P., 2009. Output, input and productivity measures at the industry level: the EU KLEMS database. Econ. J. 119 (538), F374–F403.

Oulton, N., 2007. Investment-specific technological change and growth accounting. J. Monet. Econ. 54 (4), 1290–1299.

Pagano, P., Schivardi, F., 2003. Firm size distribution and growth. Scand. J. Econ. 105 (2), 255–274.

Puch, L.A., Licandro, O., 1997. Are there any special features in the Spanish business cycle? Investig. Econ. 21 (2), 361–394.

Rodríguez-López, J., Torres, J.L., 2012. Technological sources of productivity growth in Germany, Japan, and the United States. Macroecon. Dyn. 16 (01), 133–150.

Solow, R., 1957. Technical change and the aggregate production function. Rev. Econ. Stat. 39, 212–220.