The Post-crisis Slump in Europe: A Business Cycle Accounting Analysis*

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Abstract

This paper analyses the Post-crisis slump in 28 European economies during the 2008Q1 - 2014Q4 period using the Business Cycle Accounting (BCA) method á la Chari, Kehoe and McGrattan (2007). We find that the deterioration in the efficiency wedge is the most important driver of the European Great Recession and that this adverse shock persists throughout our sample. We further investigate the potential sources of the efficiency loss and find that, firstly, the drop in TFP does not discriminate between regions within Europe, and secondly, financial variables, namely the average growth rate of equity prices and the average growth rate of non-performing loans, have a connection with real economic (mis)performance. These findings support the emerging literature on resource misallocation.

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1 Introduction

While more than seven years has past since the onset of the Great Recession, European countries have not shown any signs of recovery. Moreover, there is few consensus on why this is the case.

This paper quantitatively analyses the post-crisis slump in Europe from the beginning of 2008 until the end of 2014, with the *BCA* methodology á la Chari et al. (2007).

BCA is a useful tool to decompose business cycle fluctuations into their contributing factors. The idea behind this approach is to lead researchers into the direction of classes of economic models that give detailed understanding behind economic (mis)performances. The accounting procedure is conducted as follows. First, several exogenous frictions called wedges are defined in equilibrium conditions of a standard Real Business Cycle model. Second, the stochastic process of these wedges are structurally estimated using Bayesian estimation methods. Third, the wedges are backed out using data and the model solution. In the last step, the wedges are put back into the model, one by one, in order to recognise their relative importance over the drop in output, consumption, investment, and labour.

The BCA method has been widely applied to the analysis of specific business cycles episodes in various countries. Chari et al. (2007) focus on the U.S. Great Depression and early 1980s recession. Klein and Otsu (2013) study the International Great Depression during the interwar period. Kersting (2008) focuses on the UK recession in the 1980s. Kobayashi and Inaba (2006) and Chakraborty (2009) investigate the sources of the boom and bust in Japan during the 1980s and 1990s. Lama (2011) focuses on output drops in Latin America during the 1990s. Otsu (2010) studies the 1998 crises in East Asia. Cho and Doblas-Madrid (2013) compare 23 financial crisis episodes over the 1980 - 2001 period. Brinca (2014) studies 22 OECD countries over the 1970-2011 period. Chakraborty and Otsu (2013) analyse the growth episodes of the BRICS economies. Most of these studies show that efficiency and labour wedges are important in accounting for output fluctuations.

We contribute to the existing literature in the following ways: firstly, we dismantle Europe into 28 countries and compare the crisis experience across economies. The model parameters are calibrated and estimated to the data over the 1995Q1 - 2007Q4 period for every country individually. Secondly, by simulating the model over the 2008Q1 - 2014Q4 period we analyse not only the cross-country differences of the impact of the crisis, but also of the recovery from the crisis. This enables us to assess the linkages of economic fundamentals to wedges responsible for the post-crisis slump in European countries.

The main findings of this paper is that the distortion in the representative firm's production function (the efficiency wedge) is mainly responsible for the prevalent output drop beginning at the onset of the crisis in the early 2008. This adverse shock to *Total Factor Productivity* is persistent throughout our sample of 28 European countries. The distortion that has the second biggest quantitative impact on the observed fall in economic variables is the labour wedge that distorts the labour-market equilibrium. The remaining two wedges, the investment and the government wedge, do not impact the economy, except for few individual countries, in a significant way.

Finally we find that a subset of financial variables is significantly related to the cross-country differences in the magnitude in the efficiency wedge distortion. Variables comoving with the post-crisis level of TFP are variables capturing the average growth rate in equity markets, the average growth rate in the non-performing loans to total loans ratio, and the pre-crisis level of non-performing loans.

The reminder of this paper is structured as follows: The second section describes the data. The third section introduces the BCA model. The fourth section presents the the quantitative analysis. In section 5 we discuss possible variables that comove with predicted output performances. The same section discusses the findings and shows future research opportunities. The last section concludes.

2 Data

The data set covers data for 28 European countries, listed in table (1).[1]

Quarterly data for output, consumption, investment, labour hours (as a measure for labour input), employment, weekly working hours, total population and population younger than 15 years is obtained through *Eurostat*, using the European System of Accounts 2010-definition. The data coverage goes from 1995Q1 up to 2014Q4. The data is obtained, where applicable, in real terms. If in some periods no data exists using the ESA 2010-definition, variable-to-GDP-ratios are obtained from the European System of Accounts

[1] Full data is not available for Bulgaria, Croatia, and Switzerland.

Table 1: Sample countries

Euro Area:		
Austria	Belgium	Cyprus
Estonia	Finland	France
Germany	Greece	Ireland
Italy	Latvia	Luxembourg
Malta	Netherlands	Portugal
Slovakia	Slovenia	Spain
European Union: Euro Area plus		
Czech Republic	Denmark	Hungary
Lithuania	Poland	Rumania
Sweden	United Kingdom	
Europe: European Union plus		
Iceland	Norway	

2005-definition and thereafter multiplied by the ESA 2010 output measure and extrapolated by their respective growth rates in order to fill the gaps until ESA 2010 data for this variable is available. In some rare cases concerning total working hours, the levels have to be used using the ESA 2005-standard. If neither quarterly total hours worked exists in the ESA 2010 nor in the ESA 2005 data set, a measure for quarterly total hours worked was computed:

quarterly total hours worked=weekly hours worked * amount of weeks worked per quarter * employment[2]

In order to obtain adult population, we have to subtract population younger than 15 years from the total population variable. Since population younger than 15 years is not always available in quarterly terms, we have to divide the annual value by 4 and subtract one-by-one the fraction of the annual value from the quarterly level of total population.

Private consumption is separated into consumption of non-durable goods, semi-durable goods, durable goods, and services. The final measure for private consumption contains the values for non-durable goods, semi-durable

[2]The amount of weeks worked per quarter is taken to be 12.

goods, and services. Durable goods expenditures are added to private investment expenditures. Final total investment contains private investment, expenditures on durable goods, and public investment expenditures by the government.

In cases where the ESA 2010 data set does not allow the division between the different consumption values, we use total consumption and total investment as a measure for consumption and investment, respectively, in the estimation and simulation process.[3]

In order to be able to define a stationary problem, all variables have to be *detrended* by their respective growth trends:

$$y_t = \frac{Y_t}{N_t\Gamma_t}, c_t = \frac{C_t}{N_t\Gamma_t}, i_t = \frac{I_t}{N_t\Gamma_t}, h_t = \frac{H_t}{N_t}$$

Where Y_t is total output in time t, C_t is consumption in time t, I_t is investment in time t, and H_t is labour input in time t. Small letter variables denote detrended or *stationary* per adult population values. N_t is the level of per adult population at time t, growing at the rate $(1 + n)$, and Γ_t is the level of Total Factor Productivity in time t, growing at the rate $(1 + \gamma)$.[4,5,6] The resulting variables were converted into log values.

Figure (1) shows us the time series of output (y), consumption (c), investment (i), and labour input (h) from 2007Q4 (the last period before the onset of the crisis) until 2014Q4. The solid line with circular markers is the observed mean value of the data variable, the dashed line is a 95% bootstrap confidence interval.

We can clearly see that output and consumption starts a rapid decline in the first few quarters of the crisis. This decline lasts until the end of the observation period in the last quarter of 2014. It is important to recognise that

[3]Countries where the division of consumption and investment was not possible are: Belgium, Hungary, Iceland, Ireland, and Romania.

[4]By definition the growth rate of Total Factor Productivity must be equal to the growth rate of per adult output.

[5]Total hours worked is only detrended by dividing through per adult population, since its only trend comes from the growth in population and not from the growth in Total Factor Productivity.

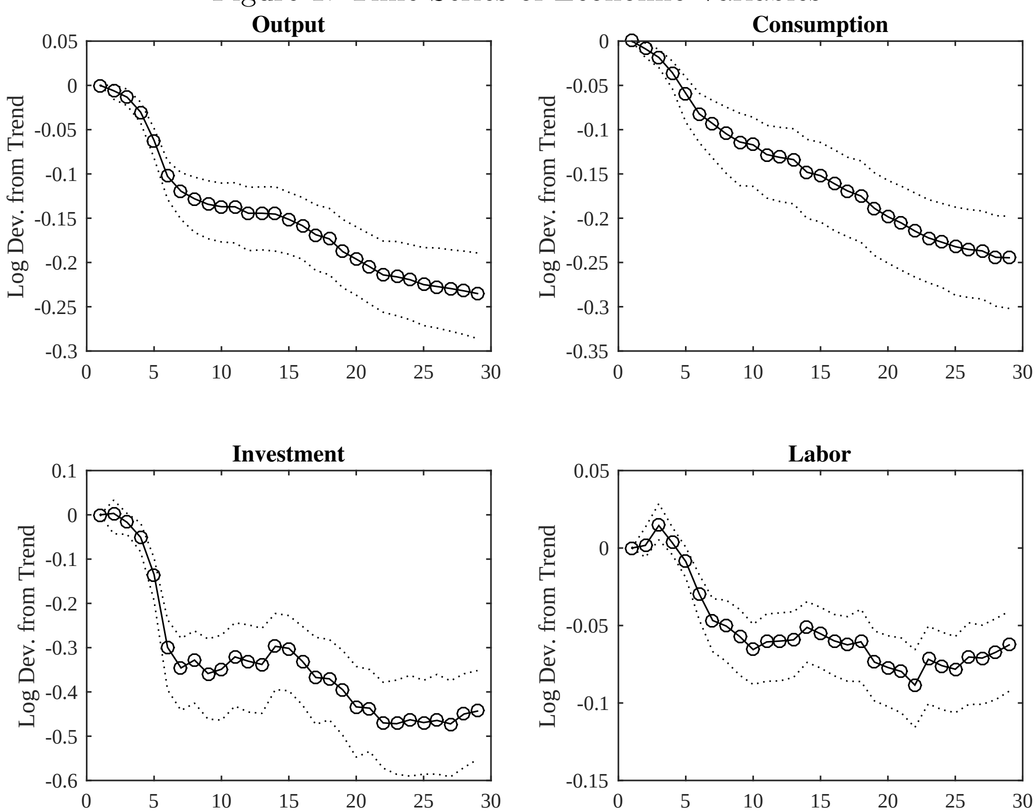
[6]Concerning the investment measure for Belgium: It is not possible to obtain investment expenditures for the time from 2011Q2 to 2014Q4 from the Eurostat database. In this case we have to compute the investment-output ratio from the OECD Economic Outlook tables and multiply it with total output as obtained by the ESA 2010 dataset.

both variables do not seem to stabilise throughout this seven-year period. At the end of 2014, average output in Europe lost almost 24% and consumption lost almost 25% of its pre-crisis level. For both cases neither the level nor the growth rate has recovered to its pre-crisis trend, hence, a recovery from the initial shock and end of the Great Recession is still wishful thinking.

Investment on the other hand shows an even more radical picture. It drops in the first six periods of the crisis by almost 35%, and is therefore more than three times the size of the drop in output during the same period. It stabilises somewhat after that just to drop by another 20% in mid-2011. At the beginning of 2013 it stabilises again and remains at this level of more than negative 45% until the end of 2014. As seen by the confidence interval, some countries even experience a drop in investment expenditures of almost 60% compared to their pre-crisis trend level.

Labour input, as measured by total hours worked per capita, sees an increase of almost 2% at the beginning of the crisis. After this increase it goes into steep decline until the beginning of 2013 and remains at the level of around negative 6% until the end of the observation period.

Figure 1: Time Series of Economic Variables



3 Benchmark Prototype Model

The benchmark prototype model's origin comes from a standard neoclassical growth model as developed by Solow (1956) and advanced into a Dynamic Stochastic General Equilibrium model by Kydland and Prescott (1982). We follow the lead of Chari et al. (2007) and restrict our analysis to a closed economy model with one representative household, that, in order to maximise lifetime utility, decides in every period over how much to consume, and hence, to save, and how much to work or enjoy leisure. The production sector is characterised by a representative firm that intents to maximise profits by periodically choosing how much labour to hire and how much capital to invest. The production technology of the firm is represented by a constant-returns to scale production function which is impacted by time-varying production efficiency. The government sector collects taxes and channels them directly back to the consumer in form of lump-sum transfers.[7]

3.1 Household's problem

The representative consumer maximises expected lifetime utility via the following problem:

$$maxE_t \sum_{t=0}^{\infty} \beta^t u(c_t, 1 - h_t)$$

Where E is the expectations operator for all future values in time t, and $\beta \in$ (0,1) is the discount factor for future consumption. Future consumption needs to be discounted since the consumer has a certain degree of impatience towards consumption occurring in the future.

The representative household gains utility from choosing consumption in time t, c_t, and leisure, as a measure of total available working hours, normalised at 1, minus actual hours worked at time t, h_t:

$$u(c_t, 1 - h_t) = \psi lnc_t + (1 - \psi)ln(1 - h_t) \tag{1}$$

ψ is a time allocation parameter.

Subject to the household's budget constraint:

$$(1 - \tau_{ht})w_t h_t + r_t k_t + \pi_t + \tau_t = c_t + (1 + \tau_{it})i_t \tag{2}$$

[7] The model used in this chapter is of the same dimension than the model used by Chari et al. (2007).

Where w_t is the wage rate at time t, r_t the real interest rate at time t, k_t the capital stock at time t, π_t profits gained by the firm and paid back to the owner of the firm at time t, τ_t lump-sum transfers paid by the government at time t, and i_t is gross capital investment expenditures at time t. τ_{ht} and τ_{it} are the tax rates for wages and investment, respectively.

The budget constraint, equation (2), tells us that the consumer's consumption and savings' decision must not exceed his income, which consists of his labour income, capital income, profits, and transfers received from the government.

And subject to the capital law-of-motion:

$$\Lambda k_{t+1} = i_t + (1 - \delta)k_t$$

Where, as before, k is capital stock in time t and t+1, i_t gross capital investment expenditures, and δ the depreciation rate. Λ is the total growth rate of the economy and can be decomposed into population growth and the growth due to increased total factor productivity.

3.2 Firm's Problem

The firm maximises profits:

$$max \pi_t = y_t - w_t h_t - r_t k_t \tag{3}$$

by choosing labour input, h_t, and capital, k_t, and thereby determining output, y_t, subject to the production function:

$$y_t = z_t k_t^{\theta} h_t^{1-\theta}$$

Where z_t is the time-varying production efficiency, and θ and $(1 - \theta)$ capital and labour intensity, respectively. Since we assume a constant returns to scale technology, we know that θ plus $(1 - \theta)$ must equal to 1.

3.3 Government

The government sector collects taxes and channels them directly back to the consumer in form of lump-sum transfers. Hence, the government's budget constraint is:

$$\tau_{ht} w_t h_t + \tau_{it} i_t = \tau_t + g_t \tag{4}$$

Where, as before, τ_{ht}, τ_{it} are the tax rates for wages and investment, respectively, and τ_t lump-sum transfers paid to the household. The variable g_t stands for government consumption.

In order to obtain the economy's equilibrium resource constraint, we simply need to substitute the government budget constraint (4) and the firm's problem (3) into the household budget constraint (2). We obtain:

$$y_t = c_t + i_t + g_t$$

3.4 Equilibrium

A general competitive equilibrium in this model occurs if there is a sequence of prices and taxes $\{w_t, r_t, \tau_{ht}, \tau_{it}\}$ from t=0 up to ∞ and quantities $\{z_t, c_t, h_t, k_{t+1}\}$ from t=0 up to ∞ such that:

i.) The household maximises utility taking prices, taxes and an initial value of k_0 as given;

ii.) the firm maximises profits taking prices and productivity as given;

iii.) labour and capital markets clear for every t;

iv.) resource constraint, equation (8), holds for every period; and

v.) the exogenous variables follow a stochastic process (as shown in section 3.5.5)[8]

Formally the equilibrium can be represented in a state where all of the following equations hold:

$$\frac{1-\psi}{\psi} \frac{c_t}{1-h_t} = (1-\tau_{ht})(1-\theta)\frac{y_t}{h_t} \tag{5}$$

[8]A sixth condition that must hold for the model to be in equilibrium is the Transversality Condition (TVC).

$$(1+\tau_{it}) = \frac{\beta}{\Lambda} E\left[\frac{c_t}{c_{t+1}}\left(\theta\frac{y_{t+1}}{k_{t+1}} + (1+\tau_{it+1})(1-\delta)\right)\right] \tag{6}$$

$$\Lambda k_{t+1} = i_t + (1-\delta)k_t \tag{7}$$

$$y_t = c_t + i_t + g_t \tag{8}$$

$$y_t = z_t k_t^{\theta} h_t^{1-\theta} \tag{9}$$

Where equation (5) is the *intra*-temporal First-order condition of labour, or the relation between the Marginal Rate of Substitution between consumption and leisure and the Marginal Product of Labour, distorted by the labour income tax, τ_{ht}.

Where equation (6) is the *inter*-temporal capital Euler equation, or the relation between the Marginal Rate of Substitution between consumption today and tomorrow and the Marginal Product of Capital, distorted by the investment tax τ_{it} and τ_{it+1}.

Equations (7), (8), and (9) are the capital law-of-motion, the resource constraint, and the production function, respectively, as discussed before.

τ_{ht}, τ_{it}, and τ_{it+1} are tax rates and become the labour wedge and the investment wedge, correspondingly, in time t and time t+1.[9]

3.5 Wedges

There are four *stochastic* and *exogenous* distortions, or wedges, that create deviations in either the first order equilibrium conditions of the model, in the relationship between input and output factors, or in the goods available in the economy:

[9]The equilibrium of the model is step by step derived in the appendix.

3.5.1 Efficiency Wedge, ω_{At}

The efficiency wedge is the relationship between the output produced in an economy and its input. It, hence, tells us something about the efficient use of limited factors of production. More commonly, the efficiency wedge can also be called *Total Factor Productivity*, and can be represented as follows:

$$\omega_{At} = z_t = \frac{y_t}{k_t^{\theta} h_t^{1-\theta}}$$

The efficiency wedge might fluctuate either due to shocks to technology, e.g., the invention of new processes or the innovation of existing ones; due to the accumulation or contraction of human capital; or due to shocks to the prices of intermediate goods like crude oil.

3.5.2 Labour Wedge, ω_{ht}

The labour wedge can be represented as a friction in the *First-Order Labour Equation* of the household. More accurate, it drives a wedge between the Intra-Temporal Marginal Rate of Substitution of consumption and leisure, and the Marginal Product of Labour, which is in a world of perfect competition equal to the prevailing wage rate in the labour market:

$$\frac{1-\psi}{\psi} \frac{c_t}{1-h_t} = \omega_{ht}(1-\theta)\frac{y_t}{h_t} \tag{10}$$

Or equivalently:

$$MRS_{ct,lt} = \omega_{ht} MPL_t$$

The labour wedge can be represented as a tax on labour income, therefore the change from (1-τ_{ht}) in the household's budget constraint (2) into ω_{ht} in equation (10). This transformation has been done because it is important to understand at this point that taxes, which were levied on labour income, only represent one of many frictions that might distort the first-order condition of labour. Cho and Doblas-Madrid (2013) argue that the entire set of wedges, and not only the labour wedge in particular, represents all kinds of frictions, distorting the first-order conditions, the resource constraint, or the production function. In case of the labour wedge, not only labour-income tax, but also monopoly power of firms and labour unions, or nominal rigidities are possible causes for sub-optimal behaviour.

3.5.3 Government Wedge, ω_{gt}

The government wedge is defined as the difference between the goods produced in an economy, and the goods available to its domestic economic agents. In terms of the model used in this chapter:

$$y_t - c_t - i_t = g_t = \omega_{gt}$$

Since we only obtain data for output, private consumption and private and public investment, we calculate government consumption as a residual term.[10]

3.5.4 Investment Wedge, ω_{it}

The investment wedge can be represented as a friction in the *First-Order Capital Euler Equation.* More accurate, it drives a wedge between the Inter-Temporal Marginal Rate of Substitution of consumption today and consumption tomorrow, and the Marginal Product of Capital, which is in a world of perfect competition equal to the real interest rate (r):

$$\omega_{it} = \frac{\Lambda}{\beta} E\left[\frac{c_{t+1}}{c_t}\left(\frac{1}{\theta\frac{y_{t+1}}{k_{t+1}} + \frac{(1-\delta)}{\omega_{it+1}}}\right)\right] \tag{11}$$

Or equivalently:

$$\omega_{it} = \frac{\Lambda}{\beta} E\left[\frac{MRS_{ct,ct+1}}{MPK_{t+1} + \frac{(1-\delta)}{\omega_{it+1}}}\right]$$

Following the same argument as in point 3.5.2, the investment wedge can be represented as a tax on investment expenditures, therefore the change from $(1+\tau_{it})$ in the household's budget constraint (2) into $\frac{1}{\omega_{it}}$ and $\frac{1}{\omega_{it+1}}$ in equation (11). As before, this alteration has been done because it is important to understand at this point that taxes, which were levied on investment

[10] Since a closed-economy model is used in order to run the business cycle accounting exercise, the government wedge also contains the impact net exports have on the availability of domestic goods.

expenditures, only represent one of many frictions that might distort the capital Euler equation. Everything that distorts the inter-temporal savings decision of consumers, like credit-market frictions, input-financing frictions, or bubbles, is accounted for by the investment wedge.

3.5.5 Stochastic Process

We assume that the exogenous variables follow a vector-autoregressive process of order 1, VAR(1):

$$S_{t+1} = PS_t + \epsilon_{t+1}$$
$$\epsilon \sim IID(0, V)$$

Where $S_t = (\omega_{At}, \omega_{gt}, \omega_{it}, \omega_{ht})'$ is the event in time t, P the 4x4 transition matrix, and $\epsilon_t = (\epsilon_{At}, \epsilon_{gt}, \epsilon_{it}, \epsilon_{ht})'$ are innovations that are independent and identical distributed and have a standard normal distribution with a mean value of zero and an unrestricted variance-covariance matrix V.[11] As we will see in section 4.2 *Estimation*, the transition matrix is of particular importance since it allows for spillover effects of the wedges to each other.

4 Quantitative Analysis

Business Cycle Accounting works in different steps: In the first step parameter values have to be found in order to define the equilibrium of the model. Those parameter values are located through the calibration and structural estimation process. In view of the estimation process, it is important to consider a time period, before the onset of the crisis, long enough for the economy to reach its steady state. In the second step the model has to be solved. Solving the model is done through linear solution methods. In the next step wedges are backed out with the help of data on output, consumption, investment and labour input. In the last step we implement the actual *Accounting Exercise*. Here we plug in one wedge at the time and simulate the model. This helps us to recognise and decompose the particular effect a distortion has on equilibrium market outcomes. Through the last step

[11] The variance-covariance matrix is unrestricted in the sense that it allows for simultaneous correlations of innovations.

Table 2: Model Parameters

Parameter	Explanation
c/y	Steady-state consumption-output ratio
i/y	Steady-state investment-output ratio
$hbar$	Normalised total hours worked
δ	Quarterly rate of depreciation
θ	Capital income share of output
Λ	Average quarterly growth rate of GDP
n	Average quarterly population growth rate
γ	Total Factor Productivity trend growth rate
y/k	Steady-state output-capital ratio
β	Subjective discount factor
ψ	Time allocation parameter

we see that the wedges prevent the model from reaching its optimal factor allocation.

4.1 Calibration

In this section we want to show which *country-specific* parameters we need to calibrate in order for the model to match the data. This is possible if we assume that every economy was in its respective steady state before the beginning of the crisis in the first quarter of 2008.

Table (2) shows an overview of the different parameters used in order to estimate and simulate the model.

The steady-state consumption-output ratio, c/y, and the steady-state investment-output ratio, i/y, are computed by averaging the values for c_t, i_t and y_t from 1995Q1 up to 2007Q4.

Normalised total hours worked is obtained by the formula:

$$\bar{h} = \frac{\textit{total hours worked}}{\textit{adult population} * 91.25 * 14}$$

Where 91.25 is the amount of days in one quarter of a year and 14 is assumed to be the maximum amount of hours that can be worked a day.

This value tells us that the population is working $\bar{h}\%$ from its potential maximum, and thus, the value must be between 0 and 1.

The *Penn World Tables 8.0* provides us with data from 1990 to 2007 that is needed in order to compute the country specific depreciation rate, δ. Data that is necessary in order to compute this variable is real GDP (expenditure approach), capital stock, and share of gross capital formation on GDP. All variables are expressed in current PPP (in mil. 2005 US Dollars). Using the capital law-of-motion and rearranging it in order to solve for δ_t, it was computed as follows:

$$\delta_t = \frac{I_t}{K_t} + 1 - \frac{K_{t+1}}{K_t}$$

For t=1990, ... ,2007. After obtaining this parameter for every individual country over 18 years, we take two different average values:

$$\delta = \frac{{}^{\delta_{1990}+\cdots+\delta_{2007}}/_{18}}{4}$$

This gives us the average quarterly rate of depreciation.

The labour share of income, $(1-\theta)$, is computed using the method developed by Gollin (2002). Gollin proceeds in two steps:

i.) Naïve labour income:

$$1 - \theta^n = \frac{\textit{Compensation of Employees}}{\textit{Gross Domestic Income - Taxes on Production and Imports less Subsidies}}$$

ii.) Adjustment for self-employed workers:

$$1 - \theta = (1 - \theta^n)\frac{\textit{employment}}{\textit{employees}}$$

Once the labour share of income, (1-θ), is found, one only has to subtract it by 1 in order to obtain the capital share of output:

$$(1 - \theta) - 1 = \theta$$

In computing the labour income share additional data for compensation of employees, taxes on production and imports less subsidies, and employees are obtained from *Eurostat*.

In order to compute the average quarterly growth rate of GDP, Λ, we simply compute the average of all growth rates during the estimation period:

$$\Lambda = \frac{log(Y_{2007q4}) - log(Y_{1995q1})}{51}$$

To compute the average quarterly population growth rate we use the same technique as just described:

$$n = \frac{log(pop_{2007q4}) - log(pop_{1995q1})}{51}$$

Where *pop* is the level of population in the respective year.

Since the average quarterly growth rate of GDP entails the quarterly growth in the total population and the trend growth in Total Factor Productivity, and since both measures are prior computed with log-transformed data, we simply can, in order to compute the quarterly trend growth in Total Factor Productivity, subtract the growth in population from the total growth rate of GDP:

$$\gamma = \Lambda - n$$

Where γ is the quarterly trend growth rate of the level of Total Factor Productivity Γ.

The steady-state output-capital ratio, y/k, is computed with the help of the steady state capital law-of-motion:[12,13]

$$\frac{y}{k} = \frac{y}{i} * (\Lambda - 1 + \delta)$$

[12]See appendix for detailed derivation of the steady-state capital-output ratio.
[13]Small letters denote per capita values.

The subjective discount factor, β, is derived from the steady-state Capital Euler Equation:[14]

$$\beta = \frac{\Lambda}{\theta * \frac{y}{k} + 1 - \delta}$$

The last parameter that needs to be computed in order to estimate and simulate the model is the time allocation parameter, ψ. In order to derive this parameter we need to start with the steady-state First-Order Condition of Labour and finally get:[15]

$$\psi = \frac{1}{(1-\theta) * \frac{y}{c} * \frac{1-h}{h} + 1}$$

Note: Every parameter is country-specific and is computed with country-specific data only. The list of country-specific parameter values is shown in the appendix.

4.2 Estimation

In the case of the efficiency, the labour, and the government consumption wedge, it is trivial to measure their magnitude in time t. We only have to derive the decision rules (first-order conditions) with respect to the functional form of the utility and production function, equation (1) and (9) respectively, and plug in the data to calculate the deviations. In the case of the investment wedge, however, it is not so simple. That is, because in equation (11) we can see that the investment wedge today depends on expected future values of the economy's variables in time t+1, or more precise on the investment wedge in time t+1. The investment wedge in t+1 in turn depends on the investment wedge in t+2, and so on and so forth. It follows that in order to compute the investment wedge in time t, we need to understand the stochastic process governing economic variables to make inferences about how the economy is going to behave in subsequent periods, see section 3.5.5 *Stochastic Process.*

[14]See appendix for detailed derivation of beta.

[15]See appendix for detailed derivation of the time allocation parameter.

To do this we need to define a state at time t, S^t. State in the sense that we need a notion about what the underlying structure of the economy is, how it looked like yesterday, how it looks like today, and how it might look like tomorrow. The state in time t has and will be determined not only by the structure of the economy, but also by a finite number of realised random events impacting the economy at every point in time from time 0 up to time t, thus, $S^t = (S_0, \dots, S_t)$. These events, which ultimately define the state, follow a stochastic process which has the form of a vector-autoregressive process of order 1, VAR(1):

$$S_{t+1} = PS_t + \epsilon_{t+1}$$
$$\epsilon \sim IID(0, V)$$

Where, as before, $S_t = (\omega_{At}, \omega_{gt}, \omega_{it}, \omega_{ht})'$ is the event in time t, P the 4x4 transition matrix, and $\epsilon_t = (\epsilon_{At}, \epsilon_{gt}, \epsilon_{it}, \epsilon_{ht})'$ are innovations that are independent and identical distributed and have a standard normal distribution with a mean value of zero and an unrestricted variance-covariance matrix V.[16] The transition matrix is of particular importance since it allows for spillover effects of the wedges to each other.

In order to solve for the stochastic process it is important to, firstly, log-linearise the decision rules, equations (5), (6), (7), (8), and (9) around their steady-state.[17] The second step is to solve the model using the log-linearised decision rules together with the calibrated parameters, and data for output, consumption, investment, and labour. The data is used from period 0 up to period t-1, where t is the time of the onset of the crisis.[18] In the third step we estimate, through *Bayesian Maximum Likelihood Estimation*, the parameters P and V for the stochastic process of the wedges. By using this estimation procedure we treat the investment wedge as a latent variable.

This estimation process is a fundamental piece in the Business Cycle Accounting exercise. Without estimating the stochastic process of the wedges it would not be possible to proceed to the simulation or *decomposition* part as

[16] The variance-covariance matrix is unrestricted in the sense that it allows for simultaneous correlations of innovations.

[17] The process of log-linearisation can be seen in the appendix.

[18] The onset of the crisis is computed through *Multiple Breakpoint Testing*. Since the crisis did not affect every economy at the same time, we use the earliest breakpoint in order to assume conformity. The last period before the crisis is taken to be 2007Q4, and hence, in our estimation and simulation process the crisis starts in 2008Q1.

Table 3: Truncated Simulation Process

Country	**Start Date**	**Country**	**Start Date**
Belgium	1999Q1	Latvia	2000Q1
Czech Republic	1996Q1	Luxembourg	2003Q1
Estonia	2000Q1	Malta	2000Q1
Hungary	2001Q1	Poland	2000Q1
Iceland	2003Q1	Slovakia	1997Q1
Ireland	1998Q1		

Chari, Kehoe and McGrattan call it. This is so, because the effect a wedge has not only comes from the stochastic shock governing that wedge only, but also from possible correlations of shocks to the other wedges (variance-covariance matrix), or the possible influence other wedges have on the simulated wedge (transition matrix). If we, for example, simulate the model with only letting the efficiency wedge fluctuate, we might grossly underestimate the impact it has on the economy if we do not consider the effect other wedges have on the magnitude and perseverance of the efficiency wedge.

The estimation process starts in 1995Q1 and lasts until 2007Q4. These are 52 data periods where the model has time to find the stochastic process of the wedges. At this point it is important to note that the estimation procedure just described ends one period before the onset of the crisis. This is essential since we assume that the economy is in steady state before the crisis begins.

Due to some minor data issues, some countries' simulation process starts on a later date than 1995Q1. This concerns the economies in table (3).

Since the estimation period is shorter than the expected 52 periods in such cases, it is necessary to check whether the simulation process and its results are mainly driven by the reduced simulation period or whether they are robust. With this aim in mind, we in parallel simulate the model using a prior specified and generic transition matrix for the wedges and a prior specified and generic variance-covariance matrix for the innovation terms.[19] In most of the cases the simulation process does not change at all in respect to the relative important of the wedges. In cases where the relative importance of the wedges changes, the most important wedge does not lose its major importance.[20]

4.3 Business Cycle Accounting Results

This section will provide an overview about the results found in this study. The first part shows the evolution of the distortions that drive the observed economic variables in figure (1). The second outlines the aggregate simulation process. In the last part we will see a more detailed breakdown of the simulation process on a country-specific basis. Here we will realise that the relative importance of wedges might change for different sub-groups of countries.

4.3.1 Wedges

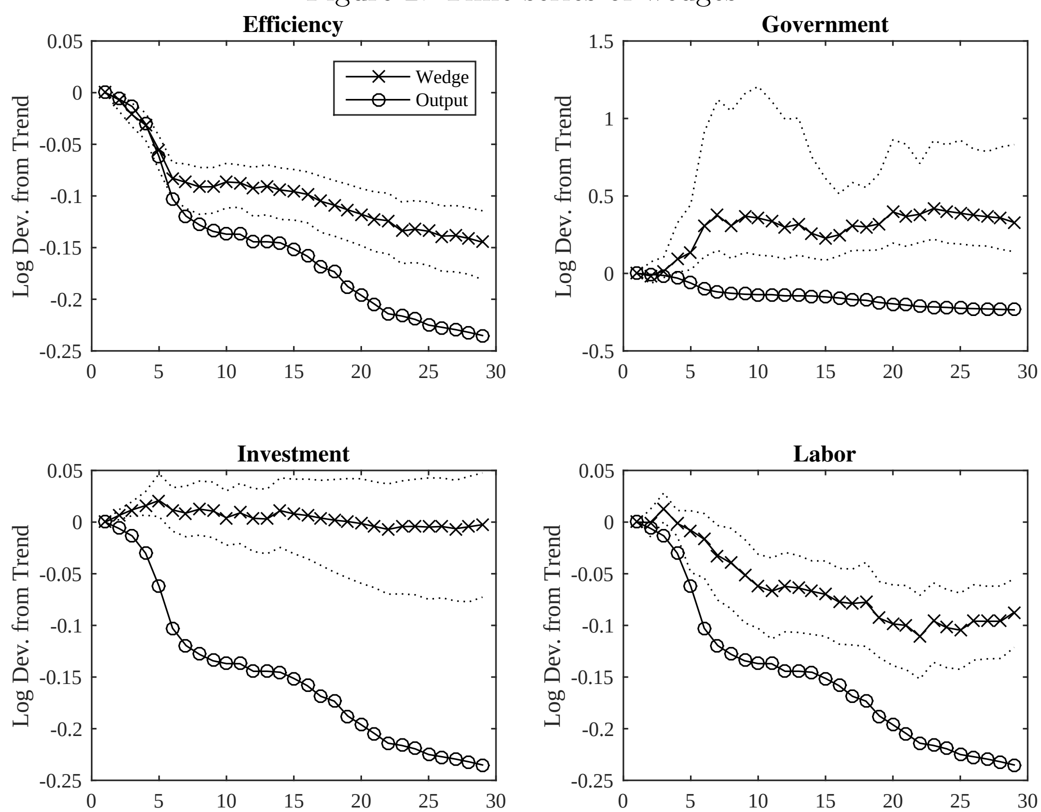
Using the Business Cycle Accounting methodology in order to find out what and where the distortions are, we compute the time series of the wedges from its steady state level at 2007Q4 until 2014Q4. Figure (2) shows their time path. The solid line with circular markers is the observed mean value of output. The solid line with crossed markers is the mean value of the simulated variable. The dashed line is a 95% bootstrap confidence interval for the simulated variable. This convention is used throughout the chapter.

Since the efficiency wedge is defined as $\omega_{At} = z_t = \frac{y_t}{k_t^{\theta} h_t^{1-\theta}}$, the labour wedge is defined as $(1 - \theta_{ht}) = \omega_{ht}$, and the investment wedge is defined as $\frac{1}{1+\tau_{it}} = \omega_{it}$, we can see all three wedges performing poorly compared to their trend level. At the beginning of the crisis the efficiency wedge begins its steep

[19]The generic transition matrix: $P = \begin{pmatrix} 0.9 & 0 & 0 & 0 \\ 0 & 0.9 & 0 & 0 \\ 0 & 0 & 0.9 & 0 \\ 0 & 0 & 0 & 0.9 \end{pmatrix}$, and the generic variance-covariance matrix: $V = \begin{pmatrix} 0.01 & 0 & 0 & 0 \\ 0 & 0.01 & 0 & 0 \\ 0 & 0 & 0.01 & 0 \\ 0 & 0 & 0 & 0.01 \end{pmatrix}$.

[20]Note that among them Belgium, Ireland, Slovakia and Czech Republic where not estimated a second time since their data coverage was sufficient in order to be reliable.

Figure 2: Time series of wedges

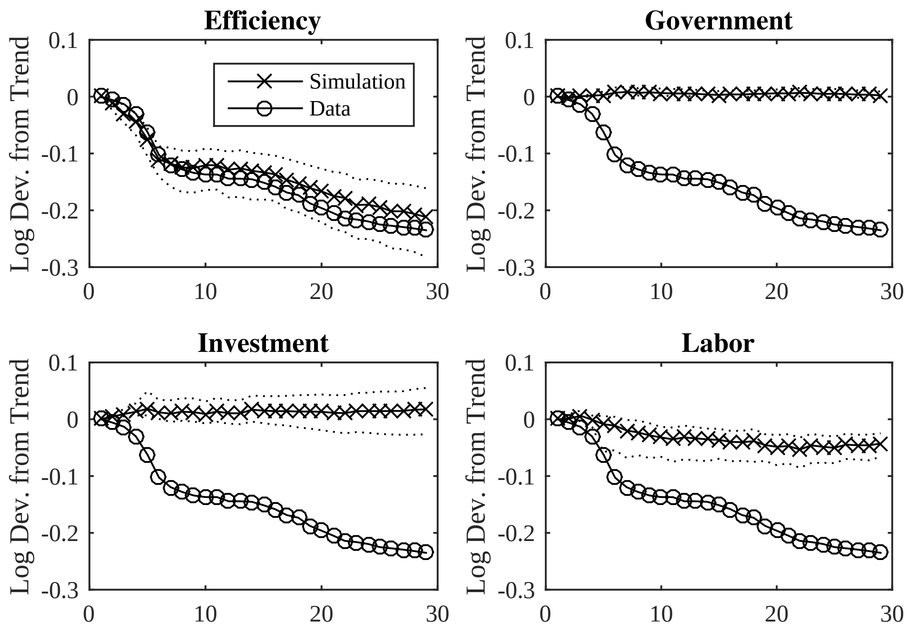


descent. At the end of the observation period it is almost 15% lower than its trend level and keeps on declining. The labour wedge jumps up slightly at the onset of the crisis, but after that starts to fall until the beginning of 2013, where it finally levels off at around negative 9%. Throughout the entire data period the investment wedge is less distorted, it even returns to its pre-crisis level in 2012, where it stabilised until the end of 2014. Government wedges rise after the crisis, reflecting fiscal stimulation policies.

4.3.2 Aggregate Simulation Results

Except for the decline in Total Factor Productivity, represented by the efficiency wedge, we cannot infer much through figure (2). We can see that all four wedges show a negative behaviour compared to their trend levels, but we still do not know whether and, if yes, to which extent they distort

Figure 3: One Wedge alone Economy - Output



the equilibrium conditions of the model. In order to assess their relative importance we need to feed the wedges, one by one, back into the prototype model and see which one has the strongest influence to the drop in output, consumption, investment and labour input. This procedure is what Chari et al. (2007) call the *Accounting Exercise*.

Figure (3) shows us the model's output drop feeding in only one wedge at a time.[21] The conclusion we get from this picture is that the one-wedge model that most closely follows observed output performance in the after-crisis period is the efficiency wedge-alone economy. In the first year of the crisis the *efficiency wedge-alone economy* moves almost simultaneously with Europe's average output. After that it moves in parallel but the gap between the model's mean and observed output drop slightly widens.[22] In 2014Q4 observed output is about negative 23.5%, whereas predicted mean output is negative 21.2%. This leaves us to conclude that feeding in the efficiency

[21]By construction feeding all 4 wedges back into the model gives us simply the observed data.

[22]Note that the observed data is still contained by the 95% confidence interval.

wedge into the prototype model accounts for more than 90% of the observed output drop in Europe. Moreover, if we continue our analysis we can observe that feeding in the government wedge does not predict any output loss at all. Considering the investment wedge-alone economy we see that output is to increase slightly by about 1.7% in 2014Q4. The distortion that closes the link between the actual output drop of 23.5% and the predicted 21.2% by the efficiency wedge, is the labour-wedge model that predicts output to fall by about 4.3%. In the bottom-right picture we can see that the labour-wedge model predicts an initial constant output time path, but a fall one year after the onset of the crisis. This complements the graph on the top-left hand side. The efficiency wedge-alone economy matches output almost one-to-one in the first year after the crisis. This is because labour does not drag output down, and the efficiency wedge distorts the market by itself. Once the labour wedge also distorts output, the efficiency wedge loses its ability to perfectly predict the drop in output, and output falls even faster than predicted by this model.

Figure (4) shows us the drop in consumption through the simulated model vs. the observed consumption drop, and goes in parallel with the arguments of figure (3). Even though the importance of the efficiency wedge and the labour wedge slightly change, the conclusion stays the same: the wedge that most closely resembles the drop consumption is the efficiency wedge. In 2014Q4 the efficiency wedge model predicts consumption to be negative 17.9% compared to an observed fall in output of negative 24.5%. Again, the labour wedge closes the link with predicting a drop in consumption of about 5.7%. As before, the models simulated with the government and the investment wedge do not predict the drop in consumption in any meaningful way.

Figure (5) emphasises the dominance of the efficiency wedge even more. We can clearly see that the efficiency-wedge model closely replicates the observed performance of investment in the post-crisis period until 2014Q4. Both the government and the labour wedge see investment slightly dropping after the crisis by about negative 3% and 4%, respectively. However, the most interesting feature here is predicted investment according to the investment wedge. The investment wedge-alone economy predicts investment to increase by about 5.5%, and therefore entirely fails to explain actual observed behaviour. Considering this finding and the drop in investment per capita

Figure 4: One Wedge alone Economy - Consumption

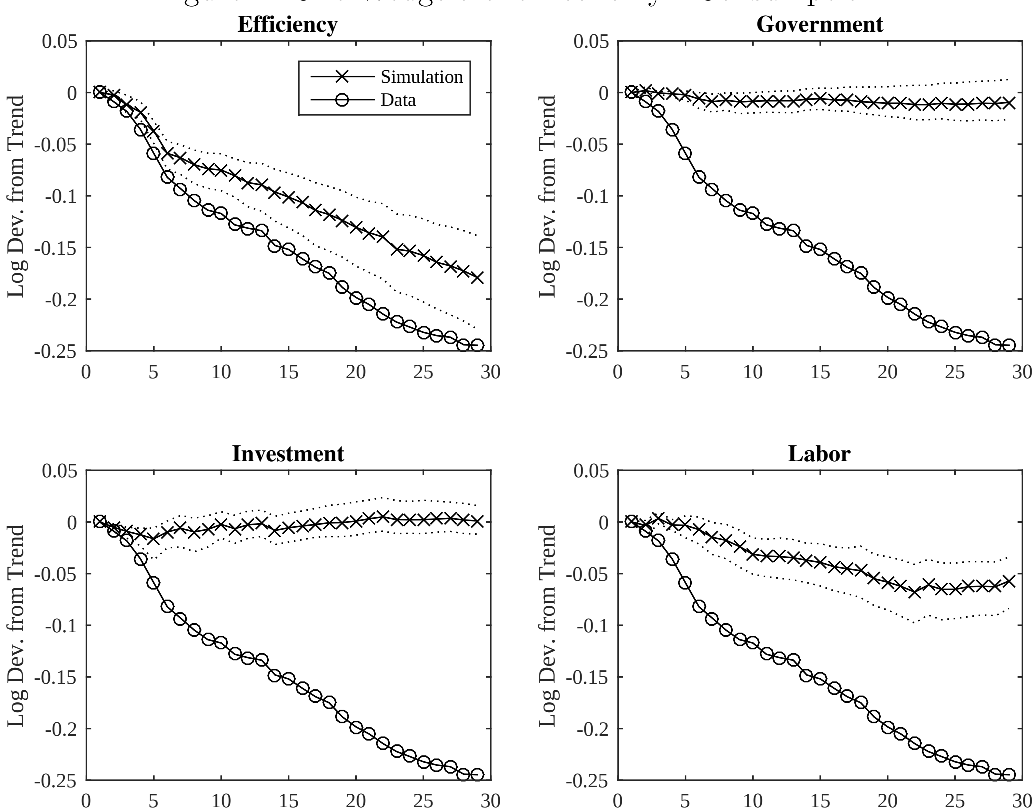
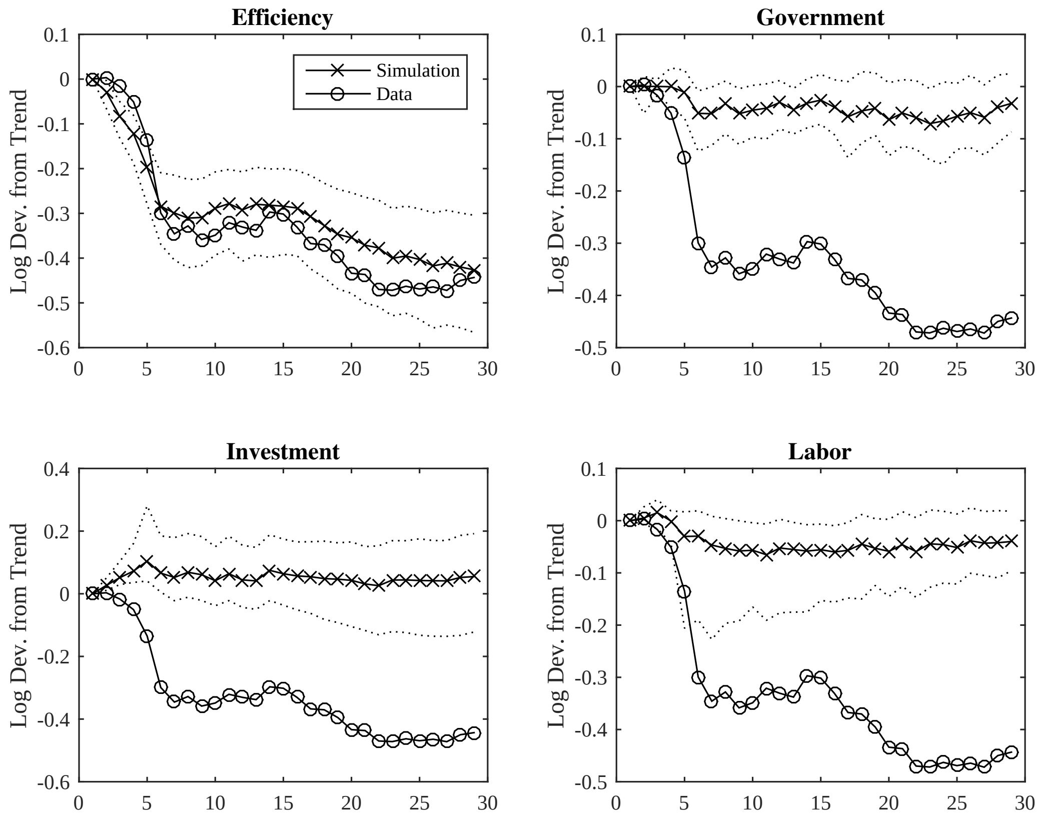


Figure 5: One Wedge alone Economy - Investment

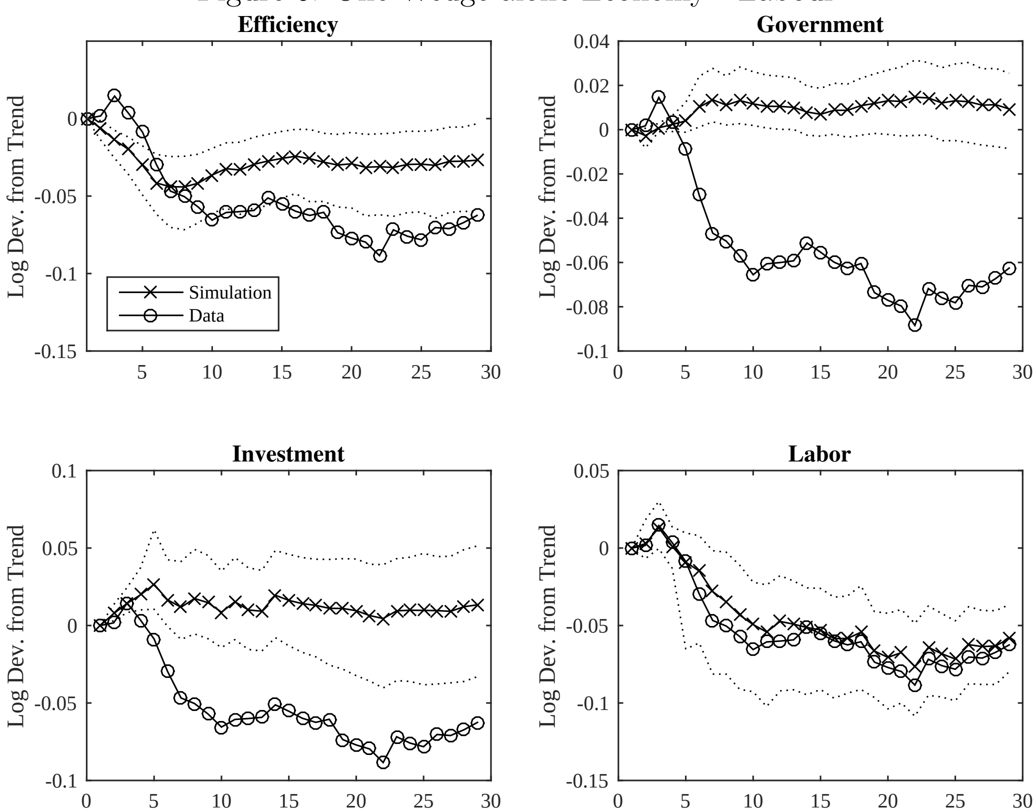


by 45%, we can conclude that an *inter*-temporal distortion, as represented by the investment wedge, does not help to explain the drop in investment. More probably, the solution will be found in an *intra*-temporal distortion, as represented by the efficiency wedge.

The last figure in this subsection is figure (6) and shows us the predicted and the observed time path of labour from 2007Q4 until 2014Q4.

This analysis gives a different picture than the simulations before. The conclusion of figure (6) is that the efficiency wedge plays only a secondary role in explaining the drop in labour during and after the crisis. The efficiency wedge-alone model predicts a drop of about negative 4% in labour after the beginning of the crisis, but levels off at around negative 2.7% until the end of the observation period. The government and the investment wedge again misinterpret the post-crisis behaviour of labour and predict an increase

Figure 6: One Wedge alone Economy - Labour



of around 0.9% and 1.3%, respectively. Here the labour wedge prediction, except for the time between 2009 and the beginning of 2011, exactly replicates the observed data in labour input. At the end of the observation period in 2014Q4 more than 93% of the observed data in labour is explained by the prototype model where the labour wedge is the only exogenous variable.

4.3.3 Country Specific Simulation Results

In this section we want to turn away from the aggregate picture in 4.3.2 and consider country specific behaviour.

Table (7) shows the loss in output for each country individually. In addition, the last four columns represent the relative importance of the wedges with respect to country-specific downturns.[23]

Out of the 28 European countries considered in this study, the first 18, Austria up to Spain, are the countries that adapted the Euro as their legal tender by the end of 2014. The following eight countries, Czech Republic up to the United Kingdom, belong, like the 18 aforementioned countries, to the European Union, but did not adopt the Euro currency as their official medium of exchange. Norway and Switzerland, the two countries at the end of the list, belong to Europe, but neither accepted the Euro as their currency, nor did they join the European Union.

The second column gives us the output loss for the time from the onset of the crisis until 2014Q14. The first thing to note here is that the only country that seems to have recovered from the crisis is Malta with a post-crisis output performance of positive 0.49%. All other countries have not come back to their pre-crisis trend level. Countries which seem to suffer the most are Latvia, Estonia, Greece, Lithuania, Cyprus, and Finland, with a loss of negative 53, 51, 49, 37, 36, and 34%, respectively. Countries with an output loss more than negative 30% sum up to 10 (when including Luxembourg as being on the margin). Countries with an output loss more than negative 20% amount to 19 (including marginal countries like Italy, Portugal, and Norway). This concludes that almost 68% of economies in our sample are negative 20% worse-off than before the crisis.

The main picture we get from this analysis is that indeed the efficiency wedge is the most important wedge explaining the drop in observed post-

[23] Country specific post-crisis behaviour with respect to consumption, investment, and labour input plus the relative importance of the wedges towards these variables can be found in the appendix.

Figure 7: Country-Specific Post-Crisis Behaviour

Country	Output Loss - 2007Q4-2014Q4	Wedge Contribution			
		ω_A	ω_g	ω_i	ω_h
Austria	-14.89%	65.29%	0.06%	27.56%	7.08%
Belgium	-13.47%	137.05%	9.24%	-27.74%	-18.54%
Cyprus	-36.00%	31.26%	4.69%	67.11%	-3.06%
Estonia	-50.69%	99.16%	1.76%	-19.99%	19.07%
Finland	-34.28%	117.70%	2.55%	-18.82%	-1.43%
France	-12.07%	86.56%	0.90%	-12.58%	25.12%
Greece	-48.87%	45.14%	2.02%	48.93%	3.91%
Germany	-5.62%	153.44%	-2.12%	-45.40%	-5.93%
Ireland	-30.95%	38.61%	3.07%	24.72%	33.60%
Italy	-19.52%	95.76%	-4.60%	-40.65%	49.49%
Latvia	-53.38%	131.17%	-1.64%	-44.89%	15.37%
Lithuania	-37.24%	107.75%	-2.39%	-39.90%	34.55%
Luxembourg	-26.03%	145.52%	-5.13%	-33.61%	-6.78%
Malta	0.49%	189.39%	-66.20%	194.81%	-218.00%
Netherlands	-21.07%	89.87%	1.17%	-22.91%	31.87%
Portugal	-19.53%	45.00%	-10.32%	13.58%	51.75%
Slovakia	-20.81%	119.17%	-4.35%	-46.64%	31.82%
Slovenia	-30.82%	139.25%	-3.48%	-50.03%	14.26%
Spain	-23.32%	23.05%	-9.32%	50.67%	35.61%
Czeck Republik	-20.19%	135.61%	0.17%	-52.01%	16.23%
Denmark	-21.64%	53.33%	7.05%	28.26%	11.36%
Hungary	-21.72%	47.30%	3.33%	41.21%	8.15%
Poland	-5.81%	91.03%	-0.29%	-8.23%	17.48%
Romania	-7.55%	30.60%	-63.92%	97.48%	35.83%
Sweden	-18.34%	112.35%	6.35%	-17.08%	-1.61%
United Kingdom	-16.62%	127.57%	3.34%	-56.09%	25.18%
Norway	-19.12%	114.50%	9.33%	-1.06%	-22.76%
Iceland	-29.25%	79.52%	-13.87%	-38.04%	72.39%

crisis output. The observed output drop in Estonia, Finland, Italy, Lithuania, Netherlands, Poland, Sweden, and Norway can almost exclusively be explained by the efficiency wedge.

However, some countries do not match that pattern. For Cyprus, Greece, Malta, Spain, and Romania the wedge that drives output is, surprisingly, the investment wedge. In their case, the efficiency wedge comes second or even third.

Nevertheless, what we have done here was only an *eyeball test*. In order to statistically prove that several countries or regions follow a similar pattern we need to run a regression model that takes account for geographical factors. The regression model in the following subsection intents to do that. Furthermore, it tries to find a relationship between the drop in TFP and variables that might measure financial distress in each economy.

5 Further Discussion

In this section we want to examine whether we can find exogenous variables that have explanatory power with respect to the drop in Total Factor Productivity (or the absolute change in the efficiency wedge) from 2007Q4 to 2014Q4. We do this by using a cross-sectional Linear Regression Model of the form:

$$\omega A_i = \alpha + \beta_z * x_{z,i} + \epsilon_i \tag{12}$$

$$\epsilon_i \sim N(0, \sigma^2)$$

Where i is the number of countries[24] in the model and z is the number of exogenous variables x. ωA_i is the change in the efficiency wedge from 2007Q4 up to 2014Q4 for country i and is assumed to be endogenous. The error term, ϵ, is country specific and normally distributed with a variance of σ^2.[25]

[24]Since Malta is an outlier in our dataset we drop it from our regression. Therefore we end up with 27 countries.

[25]The regression model is computed with robust standard errors through a heteroscedasticity consistent covariance matrix.

5.1 Variables

To get an idea about possible causes in the drop in Total Factor Productivity we include a set of variables which can potentially explain the importance of this distortion. The variables can be subdivided into two different groups:

The first group contains variables that are included to capture the state of the financial sector before and financial distress during the crisis:

- *Nonperforming Loans Avg. GR*: the average growth rate of non-performing loans to total loans for each country between 2007 and 2014

- *Nonperforming Loans Log Level 07*: the log-level of non-performing loans to total loans for each country in 2007

- *Domestic Credit Avg. GR*: the average growth rate of real domestic credit to the private sector by banks between 2007 and 2014

- *Domestic Credit Log Level 07*: the log-level of real domestic credit to the private sector by banks in 2007

- *House Price Index Avg. GR*: the average growth rate of a real house-price index between 2007Q4 and 2014Q4

- *Market Capitalisation Log Level 07*: the logarithmic value of the market capitalisation of listed companies to GDP ratio in each respective country in 2007

- *Market Capitalisation Avg. GR*: the average growth rate of the market capitalisation of listed companies to GDP ratio in each respective country between 2007 and 2012[26]

Table (4) shows the summary statistics for the above mentioned variables. The striking feature that can be seen in this table is that the average growth rates of domestic credit, of the house-price index and of the market capitalisation of listed companies to GDP ratio have negative mean and median values, implying that all three variables had a negative growth performance after the onset of the crisis until several years after.

In the second group we collect regional dummies that capture geographical differences among the countries:

[26]There was no data available for the market capitalisation of listed companies to GDP ratio in 2013 and 2014.

Table 4: Summary Statistics

Variable	Observations	Mean	Median	Std. Dev.
Nonperforming Loans Avg. GR	26	0.188397	0.16732	0.131989
Nonperforming Loans Log Level 07	24	0.234285	0.369395	1.023072
Domestic Credit Avg. GR	26	-0.015485	-0.01342	0.045496
Domestic Credit Log Level 07	26	4.517784	4.460705	0.572403
House Price Index Avg. GR	24	-0.006517	-0.009005	0.008671
Market Capitalisation Log Level 07	27	4.147667	4.11551	0.837634
Market Capitalisation Avg. GR	27	-0.15883	-0.14538	0.124059

- *Eastern Europe*: dummy reporting Eastern European countries in our sample[27]
- *Southern Europe*: dummy reporting Southern European countries in our sample[28]
- *Euro Area*: dummy reporting countries that belong to the Euro Area by the end of 2014[29]
- *Nordic Countries*: dummy reporting Nordic Countries[30]
- *BeNeLux*: dummy reporting BeNeLux countries[31]
- *British Isles*: dummy reporting countries of the British Isles[32]

[27]The Eastern European countries in our sample are: Estonia, Latvia, Lithuania, Slovakia, Slovenia, Czech Republic, Hungary, Poland, and Romania.

[28]The Southern European countries in our sample are: Cyprus, Greece, Italy, Portugal, and Spain

[29]Countries belonging to the Euro Area in our sample are: Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Luxembourg, Netherlands, Portugal, Slovakia, Slovenia, Spain.

[30]The Nordic Countries are Denmark, Finland, Iceland, Norway, and Sweden.

[31]The BeNeLux countries are Belgium, Luxembourg, and the Netherlands.

[32]Countries in the British Isles are Ireland and the United Kingdom.

5.2 Regression Results and Discussion

5.2.1 Relative contribution of wegdes regressed on regional dummies

Table (5) regresses the relative importance on the drop in output of the efficiency wedge, the investment wedge, and the labour wedge, respectively, on the regional dummies.[33]

The only significant variable in in the second column in table (5) is the dummy for Southern European countries. Its value tells us that for Southern European countries, compared to all other regional dummies, the efficiency wedge contributes to a lesser extent, by about negative 54%, to the drop in output. The insignificance of all other dummies implies that there are no differences between the other regions in the relative contribution of the efficiency wedge on the drop in real activity.

Considering the relative contribution of the investment wedge on the drop in output we can see, through the third column in table (5), that no single variable is significant. It follows that the investment wedge does not discriminate between countries: No country, or geographical region, experienced during the crisis a higher relative importance of the investment wedge on the drop in output.

The last column in table (5) shows us the relative importance of the labour wedge on the drop in output regressed on the regional dummy variables. The only apparent significant variable is the dummy for the British Isles. However, since the whole regression model is jointly insignificant, as can be see through the *Wald F-stastics* value that is bigger then the 10% threshold, the variable for the British Isles also becomes insignificant.[34]

5.2.2 Output drop regressed on regional dummies and the drop in TFP

Regression Model 1 in table (6) regresses the drop in output on the variables capturing the relative importance of the efficiency wedge, investment wedge, and labour wedge on the drop in real activity. All three variables are nega-

[33] Regression results are shown in the appendix, see tables (A3), (A4), and (A5).

[34] **Note**: In order to check for joint significance the *Wald F-statistic* must be below the 10% threshold. Since we use heteroscedasticity-consistent standard errors we need to check the *Wald F-stastic*, as opposed to the residual based *F-statistic*, for the null hypothesis of whether all non-intercept terms are equal to zero.

Table 5: Relative contribution of wegdes regressed on regional dummies

Independent Variable:	Dependent Variable:		
	OmegaA-contr.	OmegaI-contr.	OmegaH-contr.
Eastern Europe	0.087633	-0.155078	0.104598
Std. Error	(0.279915)	(0.237060)	(0.097135)
P-Value	0.7575	0.5205	0.2944
Southern Europe	-0.537252	0.380621	0.187831
Std. Error	(0.284184)	(0.282895)	(0.146564)
P-Value	0.0733	0.1935	0.2147
Euro Area	0.187437	-0.215608	-0.03964
Std. Error	(0.197796)	(0.234201)	(0.070868)
P-Value	0.3546	0.3682	0.5821
Nordic Countries	0.0871	-0.164621	-0.003388
Std. Error	(0.31247)	(0.288160)	(0.163756)
P-Value	0.7825	0.5742	0.9837
BeNeLux	0.223806	-0.179508	-0.065751
Std. Error	(0.300746)	(0.202291)	(0.16781)
P-Value	0.4654	0.3854	0.6993
British Isles	-0.093016	-0.163306	0.18652
Std. Error	(0.518674)	(0.480242)	(0.10554)
P-Value	0.8595	0.7374	0.0924
Observations	27	27	27
R^2	0.358351	0.215585	0.165679
Prob(Wald F-Statistic)	0.030327	0.137216	0.2619

Table 6: Output drop regressed on regional dummies and TFP drop

Independent Variable:	Coefficient Value	Std. Error	P-Value
Regression Model 1:			
OmegaA-contribution	-0.320064	(0.134411)	0.0259
OmegaI-contribution	-0.288765	(0.086287)	0.0028
OmegaH-contribution	-0.216936	(0.113107)	0.0676
Observations	27		
R^2	0.074696		
Prob(Wald F-Statistic)	0.009758		
Regression Model 2:			
TFP-Drop	1.244491	(0.15417)	0.0000
Observations	27		
R^2	0.711653		
Prob(Wald F-Statistic)	0.0000		

tive and significant when considering their p-values. The biggest coefficient value is, in absolute terms, the coefficient for the relative contribution of the efficiency wedge. This means that a country with a higher contribution of the efficiency wedge, relative to the investment and labour wedge, experienced a lower drop in output compared to another. More specifically, a country that experienced a higher contribution of the efficiency wedge on the drop in output of 1%, suffered an output drop that was 0.32% lower compared to all other countries in the sample. Additionally, the variables are jointly significant.[35]

Regression Model 2 table (6) shows the statistical relationship between the drop in Total Factor Productivity and the drop in output. The coefficient on the explanatory variable capturing the drop in TFP is highly significant and bigger than one. It tells us that a country that experienced an additional drop in TFP by 1% saw its output fall by around 1.25% more compared to a country where TFP did not drop. This regression model is jointly significant as seen by the *Wald F-statistic* which must be below the 10% threshold.[36]

[35] Regression results are shown in the appendix, see table (A6).

[36] Regression results are shown in the appendix, see table (A1).

5.2.3 TFP drop regressed on regional dummies and financial variables

Regression Model 1 in table (7) shows the drop in TFP regressed on the aforementioned country dummies. Except for the variables *Southern Europe*, *European Union*, and *British Isles* all variables are individually significant. The variable with the biggest coefficient value is the dummy for the Nordic Countries and has a value of 0.165. This tells us that the Nordic Countries experienced a drop in TFP of, on average, about 16.5% more than the countries not captured by this dummy. All other dummies are interpreted in a similar way accounting for the value of the coefficient.[37]

In order to find a possible relationship between the drop in Total Factor Productivity and disturbances in the financial system, we regress the drop in TFP on the aforementioned variables of financial distress in subsection (5.1). The resulting regression model is *Regression Model 2* in table (7).[38]

Out of the seven variables included, four are significant and three are insignificant at the 90% confidence level.[39] The insignificant variables are: *Domestic Credit Log Level 07*, *Market Capitalisation Log Level 07* and *Domestic Credit Avg. GR*. This claims that neither the 2007-level in domestic credit to the private sector provided by banks nor the 2007-level of market capitalisation of listed companies to GDP ratio nor the average growth rate between 2007 and 2014 of domestic credit made available to the private sector by banks are statistically significant in explaining the drop in TFP.

In spite of the statistical insignificant relationship of the latter, many economists argue in favour of the importance of domestic credit and the drop in Total Factor Productivity during the recent Global Financial Crisis.[40] They recognise that the aggregate credit growth rate is insignificant since aggregate lending behaviour did not substantially change during the crisis. Instead, the allocation of credit among firms mattered: They argue that the aggregate level of credit kept on flowing, but changed to favour

[37]Regression results are shown in the appendix, see table (A2).

[38]Regression results are shown in the appendix, see table (A7).

[39]Strictly speaking, the variable *House Price Index Avg. GR* is only "marginally" significant at a 10% threshold. Its p-value is 0.1022 as can be seen in table (A7). For convenience, and due to the small sample size, we want to consider it to be significant.

[40]Among the economists that argue for the importance of domestic credit and the drop in Total Factor Productivity during the recent Global Financial Crisis are: Shourideh and Zetlin-Jones (2012), Buera and Moll (2012), Buera and Shin (2013), Cui (2014), Khan and Thomas (2013), and Buera et al. (2015).

low-productivity firms, thereby misallocating productive capital away from their most efficient use. Their emphasis lies on the availability of credit on a firm-level basis. This point allows for the possibility that the aggregate growth rate in credit did not have to drop significantly in creating a drop in Total Factor Productivity within an economy and thus might explain the insignificance of the variable *Domestic Credit Avg. GR*.[41]

The latter idea of heterogenous borrowing and lending is what Caballero et al. (2008) already picked up on in 2008. In their paper the authors focus on this issue for the "lost decade" in Japan during the end of the 20th century and ask why TFP decreased even though total credit flowed ceaselessly. What they come up with is the idea of *Zombie lending*, or lending towards more-favoured low-productive firms away from less-favoured high-productive firms. In their theory the lending towards *Zombies* leads to a congestion in the market which pushes out more productive firms and increases the productivity gap between both, leading to a drop in aggregate TFP.

This theory not only supports why the variable *Domestic Credit Avg. GR* can be statistically insignificant, but also helps us to understand the negative and significant coefficient for *Nonperforming Loans Avg. GR*. The coefficient value of negative 0.3 tells us that a country with a 1% higher average growth rate in non-performing loans to total loans saw its TFP to drop by around 0.3% less than any other country. But how does this finding match with the theory of financial frictions and a drop in TFP? Caballero, Hoshi, and Kashyap's theory plays the key role: In our particular case that would mean that low-productivity firms were favoured during the crisis. Instead of letting their loans default, they were rolled over into newer loans in the hope of fast crisis resolution and a higher solvency in the future. While credit was directed to those low-productivity firms away from high-productivity firms, creative destruction was hampered and higher TFP thwarted. If on the contrary, and fitting with the negative coefficient value, a country did not experience this *Zombie lending*-phenomenon, low-productive firms' loans defaulted, increasing the average growth rate of non-performing loans to total loans. Since low-productivity firms had to exit the market, high-productivity firms remained and, at least, decreased the drop in TFP.

The second significant variable is *Nonperforming Loans Log Level 07* and also has a negative coefficient value. It claims that a country with a 1% higher

[41]Strictly speaking it even allows for the possibility of credit to increase during a crisis period.

2007-level of non-performing loans to total loans suffers a TFP drop that is 0.06% less than otherwise. Thus, the higher the ratio of non-performing loans to total loans in a country before the onset of the crisis, the smaller the drop in TFP during the crisis.

The third statistically (marginal-)significant variable is *House Price Index Avg. GR* and is the average growth rate of a house price index between 2007Q4 and 2014Q4. Since almost 80% of the variable values are negative and since the drop in TFP is measured in absolute terms, we need to be cautious with the interpretation of the coefficient value of negative 3.9.[42] What it eventually means is that a country with an additional 1% drop in the house-price index during the crisis episode experienced a 3.9% bigger drop in TFP compared to a country that did not experience this initial drop. Papers that support this finding are, firstly, the works by Kiyotaki and Moore (1997) and Iacoviello (2005), and secondly, the papers that discussed the interpretation of former variables [43]. Kiyotaki and Moore argue that a firm's collateralisable assets together with a financial friction parameter determine the final value of obtainable loans. Since firms are heterogeneous in their productivity and wealth, during financial crises they might be excluded from obtaining credit even though their productivity is high. This leads to a misallocation of credit from poor-but-productive firms towards rich-but-unproductive firms and decreases aggregate TFP [44]. Iacoviello (2005) pursues this idea and highlights the large proportion of real estate that is used in order to secure borrowing. In our context these theories mean that a country which experienced a higher drop in the growth rate of the house-price index also experienced a higher drop in aggregate TFP.

The last significant variable is *Market Capitalisation Avg. GR*, and is the average growth rate of the market capitalisation of listed companies to GDP ratio between 2007 and 2014. Like its preceding variable, the coefficient value is negative and has to be interpreted cautiously: It illustrates that a drop in the average growth rate of the market capitalisation of listed companies to GDP ratio by 1% increases the drop in TFP by around 0.74%.[45]

[42] For more information on the values of this variable see the summary statistics in table (4).

[43] Caballero et al. (2008), Shourideh and Zetlin-Jones (2012), Buera and Moll (2012), Buera and Shin (2013), Cui (2014), Khan and Thomas (2013), Buera et al. (2015).

[44] Remember the argument of biased allocation of capital as in Caballero et al. (2008).

[45] All the variable values are negative, giving this variable together with its negative coefficient value a positive impact towards the drop in TFP, for more insight see table (4).

A possible economic-theoretical explanation for this variable and its coefficient value is the argument of the *Financial Accelerator* developed by Bernanke and Gertler (1989) in their seminal work. In their view *Balance Sheet Effects* play the key role in borrowing and lending behaviour. But how do Balance Sheet Effects and investment connect with the above mentioned variable and the drop in TFP? The answer lies in the borrower's net worth: If the market value of the firms in a particular country falls, their equity base falls as well. This fall in firm-own equity decreases their net worth and increases their leverage. Since the companies' net worth is negatively correlated with agency costs, they increase, what leads to an increase in the external premium the companies have to pay in order to borrow funds externally. Since loans become more expensive, investment falls. Lower investment leads to less new machinery and less money spent on R&D. Both inevitably lead to a drop in TFP.[46]

Table 7: TFP drop regressed on regional dummies and financial variables

Independent Variable:	Coefficient Value	Std. Error	P-Value
Regression Model 1:			
Eastern Europe	0.160019	(0.046131)	0.0024
Southern Europe	0.049387	(0.039058)	0.2206
Euro Area	0.098602	(0.048482)	0.0555
Nordic Countries	0.167644	(0.042153)	0.0007
BeNeLux	0.093177	(0.043590)	0.0451
British Isles	0.074604	(0.076647)	0.3420

Continued on next page

[46]For a more comprehensive discussion on the effects of investment, R&D, and technological change see Romer (1989).

Table 7 – continued from previous page

Independent Variable:	Coefficient Value	Std. Error	P-Value
Observations	27		
R^2	0.358542		
Prob(Wald F-Statistic)	0.000904		
Regression Model 2:			
Domestic Credit Log Level 07	-0.013640	(0.029980)	0.6566
Market Capitalisation Log Level 07	-0.019413	(0.015405)	0.2298
Domestic Credit Avg. GR	-0.335941	(0.318406)	0.3106
Nonperforming Loans Avg. GR	-0.304433	(0.115940)	0.0210
Nonperforming Loans Log Level 07	-0.060835	(0.007161)	0.0000
House Price Index Avg. GR	-3.900033	(2.217753)	0.1022
Market Capitalisation Avg. GR	-0.742845	(0.172719)	0.0009
Observations	21		
R^2	0.874805		
Prob(Wald F-Statistic)	0.000002		

The *Collateral Constraint*, as well as the *Financial Accelerator* argument build upon the assumption that models need to take heterogeneous agents into account. According to these theories, models advocating financial shocks and homogeneous agents, like the paper by Jermann and Quadrini (2012), are unable to identify real observed economic behaviour. Indeed, the argument that in times of financial turmoil macro data only gives a limited perspective has a long-lasting tradition: Gertler and Gilchrist (1994) state that to correctly understand cyclical behaviour to financial shocks one must consider firm level responses to their respective access to capital markets. They model this heterogeneity by assuming that the firm size is a good proxy for capital market access. In their opinion, large firms, as measured by gross nominal assets, have more possible access to capital markets and are therefore less hit by adverse financial shocks, compared to small firms. Fort et al. (2012) extent the former study. Instead of only focusing on the size of firms, they also consider the age of firms and find the same conclusion: that is to say, small young firms are disproportionally hit in times of financial crisis. Furthermore, Shourideh and Zetlin-Jones (2012) distinguish between publicly traded and privately held firms. Publicly traded firms have abundant financial capital and are therefore independent of shocks to the financial market.[47] Privately held firms, in contrast, finance their investment through borrowing, and are therefore directly hit in times of financial disruptions. Aggregating both kinds of firms together leads to the conclusion that all firms have sufficient internal capital in order to invest, and are therefore *not* vulnerable to a credit crunch. However, this is only possible because publicly held firms have an excess of internal funds that overpowers the shortage of privately held firms' capital endowment.

A paper that surveys models that emphasise the importance of heterogeneous agents and financial frictions is the paper by Khan and Thomas (2013). The authors subdivide models with financial frictions into three categories: The first category represents financial frictions through *collateralised borrowing constraints* arising from the limited enforceability of debt contracts. The second class characterises financial frictions through *constrained-optimal dynamic contracts* also under limited enforceability. The third group abstracts from the limited enforceability issue and models financial frictions through existing *state verification costs* due to *agency costs* and *risk premiums*.[48]

When contrasting the theory of the *collateral constraints* with the aggregate results in section 4.3.2, and assuming it was a financial shock that hit the European economy, we might identify a close connection: Figure (1) shows us that immediately at the onset of the crisis output per working age population, consumption per working age population, investment per work-

[47] One might think of the publicly held firm's ability to raise equity through the stock market.

[48] The seminal paper by Kiyotaki and Moore (1997) builds up a model where financial frictions take the form of collateral bowing constraints. A paper that advocates constrained-optimal dynamic contracts as financial frictions is the work by Cooley et al. (2004). Bernanke and Gertler (1989), Carlstrom and Fuerst (1997), and Bernanke et al. (1999) model the source of financial frictions through the lens of agency costs.

ing age population, and labour input per working age population grossly underperform. After the initial shock and the steep decline, all variables, except for consumption which keeps on declining at a similar rate, decline at a slower rate until the end of 2014. Thus, comparable with the theory, the initial steep drop might be the time when credit conditions tighten, cutting down the credit available in the economy and allocating resources to less productive but more solvent firms. Once the credit crunch recovers, about 8 periods after it started, economic variables keep on declining, but at a lower rate. This second stage is the time when the collateral constrain still keeps on impeding the capital reallocation process, even though financial frictions returned to pre-crisis levels.

Pursuing the argument of the last paragraph: the theory argues that the majority of the economy's misperformances must be due to a worsening of aggregate TFP. Figure (2) shows us the time series of the equilibrium distortions -wedges-. On the top left-hand side we can see the distortion of the firm's production function, or the efficiency wedge. This wedge resembles Total Factor Productivity, because it distorts the relationship between input and output, see section 3.5.1. The picture shows that TFP plummets at the beginning of the crisis and keeps on decreasing until the last quarter of 2014. Following this argument, figure (3), (4), and (5) show us that output, consumption, and investment, respectively, fall due to the influence of the deteriorating efficiency wedge. This is discernible because in all three cases TFP is the distortion that enables the simulated variable to be closest to the observed variable.

Regression Model 2 in Table (7) connected with the different theories of financial frictions, we have seen in this section, shows us that the country-specific drop in TFP might indeed be associated with major distress in global financial systems that occurred at the beginning in 2008. Thus, we argue that our findings are insightful and direct attention towards the misallocation of capital due to financial market imperfections.

6 Conclusion

In this work we reviewed the European economic experience from the onset of the Great Recession in early 2008 until the end of 2014. We found that on average the drop in efficiency wedges accounts for more than 90% in the fall in output in the 28 European economies. Efficiency wedges are important in accounting for consumption and investment as well. Labour wedges, however, account for more than 93% of the drop in labour. This leads us to conclude that researchers, focusing on the detailed propagation mechanism leading to the fall in output during the Great Recession, find their answer in channels distorting the production efficiency measure of countries rather than investment market distortions.

Furthermore, we find that the cross-country differences in the drop of efficiency wedges are highly associated with the growth rate in asset prices, the growth rate in non-performing loans, and the pre-crisis level of non-performing loans. This is consistent with literature that focuses on firm-level capital misallocation as a source of efficiency loss. Future study should investigate whether the efficiency wedge drop during the Great Recession was driven by increased misallocation due to the financial turmoil.

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A Regression tables

Table A1: TFP and Output

Dependent Variable: OUTPUT_DROP
Method: Least Squares
Date: 10/07/15 Time: 12:36
Sample: 1 27
Included observations: 27
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.056688	0.028033	2.022194	0.0540
TFP_DROP	1.244491	0.154170	8.072172	0.0000

R-squared	0.711653	Mean dependent var	0.243997
Adjusted R-squared	0.700119	S.D. dependent var	0.127274
S.E. of regression	0.069697	Akaike info criterion	−2.418128
Sum squared resid	0.121442	Schwarz criterion	−2.322140
Log likelihood	34.64473	Hannan-Quinn criter.	−2.389586
F-statistic	61.70101	Durbin-Watson stat	2.223779
Prob(F-statistic)	0.000000	Wald F-statistic	65.15996
Prob(Wald F-statistic)	0.000000		

Table A2: Regional Dummies and TFP

Dependent Variable: TFP_DROP
Method: Least Squares
Date: 10/14/15 Time: 09:35
Sample: 1 27
Included observations: 27
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	−0.020982	0.050669	−0.414102	0.6832
EASTERN_EUROPE	0.160019	0.046131	3.468808	0.0024
SOUTHERN_EUROPE	0.049387	0.039058	1.264466	0.2206
EURO_AREA	0.098602	0.048482	2.033799	0.0555
NORDIC_COUNTRIES	0.167644	0.042153	3.977031	0.0007
BENELUX	0.093177	0.043590	2.137576	0.0451
BRITISH_ISLES	0.074604	0.076647	0.973341	0.3420

R-squared	0.358542	Mean dependent var	0.150511
Adjusted R-squared	0.166105	S.D. dependent var	0.086275
S.E. of regression	0.078784	Akaike info criterion	−2.025798
Sum squared resid	0.124139	Schwarz criterion	−1.689840
Log likelihood	34.34827	Hannan-Quinn criter.	−1.925900
F-statistic	1.863164	Durbin-Watson stat	1.366518
Prob(F-statistic)	0.137475	Wald F-statistic	6.123193
Prob(Wald F-statistic)	0.000904		

Table A3: Relative importance of efficiency wedge
Dependent Variable: OMEGAA_CONTRIBUTION
Method: Least Squares
Date: 10/14/15 Time: 09:35
Sample: 1 27
Included observations: 27
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.830222	0.320311	2.591925	0.0174
EASTERN_EUROPE	0.087633	0.279915	0.313072	0.7575
SOUTHERN_EUROPE	−0.537252	0.284184	−1.890506	0.0733
EURO_AREA	0.187437	0.197796	0.947626	0.3546
NORDIC_COUNTRIES	0.087100	0.311247	0.279841	0.7825
BENELUX	0.223806	0.300746	0.744168	0.4654
BRITISH_ISLES	−0.093016	0.518674	−0.179335	0.8595

R-squared	0.358351	Mean dependent var	0.912064
Adjusted R-squared	0.165857	S.D. dependent var	0.402322
S.E. of regression	0.367446	Akaike info criterion	1.053935
Sum squared resid	2.700336	Schwarz criterion	1.389893
Log likelihood	−7.228122	Hannan-Quinn criter.	1.153833
F-statistic	1.861617	Durbin-Watson stat	2.375489
Prob(F-statistic)	0.137773	Wald F-statistic	2.978247
Prob(Wald F-statistic)	0.030327		

Table A4: Relative importance of investment wedge

Dependent Variable: OMEGAI_CONTRIBUTION
Method: Least Squares
Date: 10/14/15 Time: 09:36
Sample: 1 27
Included observations: 27
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.114246	0.308073	0.370842	0.7147
EASTERN_EUROPE	−0.155078	0.237060	−0.654171	0.5205
SOUTHERN_EUROPE	0.380621	0.282895	1.345449	0.1935
EURO_AREA	−0.215608	0.234201	−0.920610	0.3682
NORDIC_COUNTRIES	−0.164621	0.288160	−0.571285	0.5742
BENELUX	−0.179508	0.202291	−0.887373	0.3854
BRITISH_ISLES	−0.163306	0.480242	−0.340050	0.7374

R-squared	0.215585	Mean dependent var	−0.065242
Adjusted R-squared	−0.019739	S.D. dependent var	0.415401
S.E. of regression	0.419481	Akaike info criterion	1.318816
Sum squared resid	3.519284	Schwarz criterion	1.654774
Log likelihood	−10.80402	Hannan-Quinn criter.	1.418714
F-statistic	0.916119	Durbin-Watson stat	2.280904
Prob(F-statistic)	0.503793	Wald F-statistic	1.864507
Prob(Wald F-statistic)	0.137216		

Table A5: Relative importance labour wedge

Dependent Variable: OMEGAH_CONTRIBUTION
Method: Least Squares
Date: 10/14/15 Time: 09:36
Sample: 1 27
Included observations: 27
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.127212	0.110975	1.146316	0.2652
EASTERN_EUROPE	0.104598	0.097135	1.076827	0.2944
SOUTHERN_EUROPE	0.187831	0.146564	1.281566	0.2147
EURO_AREA	−0.039640	0.070868	−0.559356	0.5821
NORDIC_COUNTRIES	−0.003388	0.163756	−0.020689	0.9837
BENELUX	−0.065751	0.167810	−0.391817	0.6993
BRITISH_ISLES	0.186520	0.105540	1.767302	0.0924

R-squared	0.165679	Mean dependent var	0.177786
Adjusted R-squared	−0.084617	S.D. dependent var	0.220069
S.E. of regression	0.229191	Akaike info criterion	0.109889
Sum squared resid	1.050568	Schwarz criterion	0.445847
Log likelihood	5.516493	Hannan-Quinn criter.	0.209787
F-statistic	0.661934	Durbin-Watson stat	1.858235
Prob(F-statistic)	0.680932	Wald F-statistic	1.403221
Prob(Wald F-statistic)	0.261900		

Table A6: Output drop and relative importance of wedges
Dependent Variable: OUTPUT_DROP
Method: Least Squares
Date: 10/07/15 Time: 14:52
Sample: 1 27
Included observations: 27
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.555645	0.138007	4.026221	0.0005
OMEGAA_CONTRIBUTION	−0.320064	0.134411	−2.381239	0.0259
OMEGAI_CONTRIBUTION	−0.288765	0.086287	−3.346556	0.0028
OMEGAH_CONTRIBUTION	−0.216936	0.113107	−1.917974	0.0676

R-squared	0.074696	Mean dependent var	0.243997
Adjusted R-squared	−0.045996	S.D. dependent var	0.127274
S.E. of regression	0.130168	Akaike info criterion	−1.104023
Sum squared resid	0.389707	Schwarz criterion	−0.912047
Log likelihood	18.90431	Hannan-Quinn criter.	−1.046938
F-statistic	0.618897	Durbin-Watson stat	1.880642
Prob(F-statistic)	0.609849	Wald F-statistic	4.792952
Prob(Wald F-statistic)	0.009758		

Table A7: TFP and financial variables

Dependent Variable: TFP_DROP
Method: Least Squares
Date: 10/16/15 Time: 16:45
Sample (adjusted): 1 25
Included observations: 21 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.240554	0.125984	1.909404	0.0785
DOM_CREDIT_LOG_LEVEL_07	−0.013640	0.029980	−0.454957	0.6566
MARKET_CAPITAL_07	−0.019413	0.015405	−1.260185	0.2298
DOM_CREDIT_AVG_GR	−0.335941	0.318406	−1.055071	0.3106
NONPERF_LOANS_AVG_GR	−0.304433	0.115940	−2.625795	0.0210
NONPRF_LOAN_LOG_LEVEL_07	−0.060835	0.007161	−8.494828	0.0000
HOUSE_PRICE_INDEX_AVG_GR	−3.900033	2.217753	−1.758552	0.1022
MARKET_CAPITAL_AVG_GR	−0.742845	0.172719	−4.300885	0.0009

R-squared	0.874805	Mean dependent var	0.163626
Adjusted R-squared	0.807392	S.D. dependent var	0.089163
S.E. of regression	0.039131	Akaike info criterion	−3.361461
Sum squared resid	0.019906	Schwarz criterion	−2.963548
Log likelihood	43.29535	Hannan-Quinn criter.	−3.275104
F-statistic	12.97683	Durbin-Watson stat	1.633928
Prob(F-statistic)	0.000060	Wald F-statistic	23.17538
Prob(Wald F-statistic)	0.000002		