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Energy crisis and inequality

A dual approach to assess fiscal policy effectiveness

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Abstract

Looking at the current situation in Europe, characterized by the prosecution of the war, the energy crisis, and high inflation, this research paper will tackle the effect of an energy supply shock on inequality and evaluate a possible fiscal policy response. Firstly, a model will be designed with the energy production sector and heterogeneous agents. This allows the study of the transmission mechanism of the shock and the unequal impact that it has on households, that differ for their marginal propensity to consume and energy expenditure share. Through this framework, it will also be possible to assess the outcome of the value-added tax (VAT) cut on electricity prices, implemented by the Belgian government to mitigate the effects of the crisis. Secondly, using the data on electricity prices in Belgium for 2017-2022, will be possible to estimate the pass-through rate of the VAT cut on consumers' prices, and consequently assess the effectiveness of this fiscal policy.

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Contents

1 Introduction

This research paper focuses on the current energy crisis in Europe, looking at the negative effect of rising electricity prices on inequality. The study is structured in two distinct parts: a General Equilibrium model with heterogeneous agents, energy sector and government intervention, and an empirical analysis of the value-added tax (VAT) incidence on energy prices. The model is calibrated on Belgian data. In particular, the magnitude of the shock reflects the increase in energy prices that Belgium has experienced, and the constrained households' share matches the one estimated for the country. In this way, it is possible to simulate the impact of the shock and then the effect of the fiscal policy introduced by the government. On the other hand, through a difference-in-difference regression on data from a main Belgian electricity provider, the shift of the VAT cut on customers' prices can be estimated and the effectiveness of the policy assessed.

Results from the model simulation clearly show an unequal effect on agents, with financially constrained households hit harder by the crisis. Moreover, introducing the VAT cut policy in the model seems to mitigate the negative effect of the shock, reducing the burden on constrained agents. Concerning the empirical analysis of VAT incidence, results show that there was an over-shifting of the tax, suggesting the policy implementation was effective with firms passing on even more than the tax reduction to final users' prices. However, due to the limited sample size and the on going nature of the event, the results are not statistically significant. To obtain more robust conclusions regarding the pass-through rate estimation, it will be necessary to wait until end of 2023 to gather additional energy price data and increase the number of observations. Additionally, due to the endogeneity of the reform, alternative specifications may be required. These initial findings are therefore considered preliminary and warrant further investigation.

The paper is structured as follows. Section 2 describes the background literature on the topic and its relevance to this research. Section 3 describes and derives the Heterogeneous Agent model, defines the General Equilibrium, and reports the simulation results of the shock and the policy implementation. Section 4 is dedicated to the VAT cut analysis, including the data description, the empirical strategy implemented, and its results. Section 5 concludes.

2 Related Literature

There is extremely fast-growing literature in macroeconomics on both energy shock transmission and heterogeneity. On one side, the current situation, the energy crisis and the return of high levels of inflation had shifted once again the attention to the energy market and the role of energy prices in economic dynamics (Ciola, 2022, Bachmann, 2022). On the other hand, in the last decades, macroeconomic literature is dealing with heterogeneity and is building a complex apparatus of Heterogeneous Agents Models not only to study inequality but also how shocks and policy transmission channels change if agents differ for income composition, asset market participation, marginal propensity to consume and other important characteristics. Most of these models combine these heterogeneity elements with price rigidities, incorporating in this way New Keynesian features, and so constituting the so-called HANK models (Kaplan and Violante 2018, Kaplan, Moll, and Violante 2020, Auclert, Rognlie, and Straub, 2020, Kaplan and Violante, 2022). At the same time, two agents models (TANK) were introduced to complement HANK literature, since they simplify heterogeneity to only two types of agents but have the advantage to be tractable (Bilbiie, 2008; Debortoli and Galì, 2017; Bilbiie, 2018; Bilbiie, 2020; Bilbiie and Ragot, 2021; Cantore and Freund, 2021). This paper structures the model following Bilbiie (2008), in considering an economy with two agents, constrained and unconstrained households. However, this study abstracts from Keynesian rigidities, but it could be easily extended to include them.

Another important references for this research, are the models developed to address climate change urgency, which studies implementation of environmental policies. Such literature interrelates closely with both the energy market and heterogeneity. First, because the energy sector is of first interest for transition. Second, because there is a fundamental trade-off between inequality and environmental sustainability. Therefore, researchers are trying to address how to mitigate the burden of transition that is threatening mostly the disadvantaged part of the World's population (Ponta et al., 2018, Känzig, 2022). In particular, Känzig (2022) studies the unequal effect of carbon pricing in a two-agent model, which framework and results give some useful insights also for the research question of this paper. Indeed, a carbon tax also represents an exogenous increase in energy prices. However, there are two relevant differences between these two contexts: the energy shock considered in this paper implies a reduction in energy supply, and the magnitude of the price increase is much higher than when looking at the carbon tax introduction.

Finally, very recent works have already related heterogeneity with energy shocks. In particular, Pieroni (2022)[1] examines the impact of an energy shortage in a HANK framework. The study reveals that low-income households bear a disproportionately heavier burden during energy crises. This paper also explores the effects on inequality using the GINI index and paves the way for a normative analysis. Moreover, Chan, Diz, and Kanngiesser (2022) [2] consider an open two-agent economy and study optimal monetary policy response to an energy shock. Lastly, Auclert, Monnery, Rognlie, and Straub (2022) [3] also consider an open economy, where energy is imported and the shock is on foreign price. Then they evaluate fiscal and monetary policy, both in isolation and coordination. To be noticed, they consider energy only as a consumption good and not as a production input. These contributions were very useful in developing the model presented in this research paper, which tries to address similar research questions. Moving through this complex theoretical context, continuously changing and updating, this study analyses the effect of an energy supply shock, featuring it as a negative total factor productivity (TFP) shock in the energy production sector. This identification, to the best of author's knowledge, is implemented here for the first time, to capture the effects of the current energy crises, which causes are several and complex, and not only related to price increase of imported energy inputs. Moreover, the analysis focuses on a specific country, Belgium, and it aims to evaluate fiscal policy intervention, with a particular focus on the VAT cut policy.

Concerning the literature background for the analysis of the VAT cut pass-through, the main reference is Hindriks and Serse (2022). In this research indeed, the authors examine the incidence of the VAT cut implemented by the Belgian government in 2014 and find a 100% shift of the tax cut. However, such a context was very different from the one studied in this paper. In 2014 the fiscal reform was completely exogenous with respect to the energy market, it was a political measure implemented by the government and then abolished by the next political coalition, with no interaction with the electricity market. Instead, the current VAT cut was driven by the intention to respond to the sharp increase that electricity prices performed from the end of 2021. Moreover, the 2014 VAT cut was temporary and data were available before and after the period of the reform. Nowadays instead, the VAT cut is still in place, and so there are no observations yet of the post-reform period. Despite these differences, which will lead

[1]"Energy Shortages and Aggregate Demand: Output Loss and Unequal Burden from HANK"
[2]"Energy Prices and Household Heterogeneity: Monetary Policy in a Gas-TANK"
[3]"Managing an Energy Shock with Heterogeneous Agents: Fiscal and Monetary Policy"

to different conclusions on the VAT shifting, is possible to apply a similar empirical strategy, which consists in a DiD analysis that takes firms' energy prices as a control group, since firms do not pay the VAT. The paper, therefore, contributes also to the empirical literature on VAT incidence. Studies related to energy market VAT include Fabra, Reguant (2014) and Hintermann (2016) on emission permits in Europe, which reported that such permits are almost entirely shifted to electricity prices. Futhermore, there are studies on fuel prices VAT pass-through in the US (Doyle, Samphantharak, 2008, Marion, Muehlegger, 2011). However, there is a lack of research concerning specifically electricity VAT.

3 Heterogeneous Agents Model

The model that will be used to study the effect of the energy shock on inequality is a two-agent model. The two types of agents, following Bilbiie (2008), are Savers and Hand-to-mouth, respectively with low and high marginal propensity to consume (MPC). The difference in MPC is bacause Savers have access to financial markets, while Hand-to-mouth agents do not. Therefore, Savers can save and accumulate capital income, while Hand-to-mouth cannot save, and they have to consume everything they earn each period. Agents supply labor inelastically, so they work the same amount of hours, which is normalized to 1. Consequently, they collect the same labor wage. Households' utility depends only on the consumption of the final good and the energy good. The second source of heterogeneity, following Känzig (2022), is that Hand-to-mouth agents spend a larger share of their income on energy goods compared to Savers. Notice that the quota of Hand-to-mouth agents (λ) is constant over time, so agents cannot switch types. The production block is divided into two sectors: energy firms, and final good firms. Energy good is used in the production of final good and is directly consumed by households. Furthermore, capital (k_t) is the only asset, available for Savers.

3.1 Households

3.1.1 Saver Problem

The inter-temporal problem of Savers consists in the maximization of expected utility, subject to the budget constraint and the law of motion of capital, which together constitutes the constraint (2)[4]. Savers maximize a Constant Elasticity of Substitution (CES)

[4]Law of motion of capital: $k_{t+1} = i_t + (1-\delta)k_t$ where δ is the capital depreciation rate

Utility function, which depends positively on consumption $x_{S,t}$. Consumption is an aggregation of two different goods, final and energy goods. The intertemporal elasticity of substitution is $\frac{1}{\sigma}$ and the problem can be written in recursive form, as follows:

$$V^s(k_t) = \max_{x_{S,t},k_{t+1}} \frac{x_{S,t}^{1-\sigma}}{(1-\sigma)} + \beta E_t V^s(k_{t+1}) \tag{1}$$

such that

$$p_{s,t}x_{s,t} + \frac{k_{t+1}}{1-\lambda} - \frac{(1-\delta)k_t}{1-\lambda} = w_t h_t + r_t \frac{k_t}{1-\lambda} \tag{2}$$

where $p_{S,t}$ is the price of Savers consumption bundle, r_t is the real interest rate, w_t is real labor wage and h_t are hours worked, normalised to 1.

The First Order Conditions (FOCs), with respect to $x_{S,t}$ and k_{t+1} read as follows:

w.r.t. $x_{S,t}$: $p_{S,t}x_{S,t}^{-\sigma} = \mu_{S,t}$

w.r.t. $k_{t+1} : \beta E_t V_k^S(k_{t+1}) = \mu_{S,t}/(1-\lambda)$
where $\mu_{S,t}$ is the Lagrangian multiplier associated with constraint (2).
To solve the FOC for capital, it is necessary to apply the Envelope theorem to get the expression for $V_k^S(k_{t+1})$.

$V_k^S(k_{t+1}) = \frac{\mu_{S,t+1}}{(1-\lambda)}(1+r_{t+1}-\delta)$

substituting it in the FOC :

w.r.t. $k_{t+1} : \beta E_t \mu_{S,t+1}(1+r_{t+1}-\delta) = \mu_{S,t}$

From the two FOCs, is obtained the Euler equation for Savers:

$$p_{S,t}x_{S,t}^{-\sigma}/p_{S,t+1}x_{S,t+1}^{-\sigma} = \beta(1+r_{t+1}-\delta) \tag{3}$$

which represent the optimal consumption path for Savers.

3.1.2 Hand-to-mouth problem

The problem of Hand-to-mouth consists in the maximization of the CES utility function, which depends on consumption $x_{H,t}$, subject to their budget constraint.

$$\max_{x_{H,t}} \frac{x_{H,t}^{1-\sigma}}{1-\sigma} \tag{4}$$

s.t.

$$p_{H,t}x_{H,t} = w_t h_t \tag{5}$$

where $p_{H,t}$ is the price of Hand-to-mouth consumption bundle. Notice that Hand-to-mouth agents don't face an intertemporal problem. Since they cannot save, they have to consume everything they earn each period; it is not necessary to solve the problem since consumption can be obtained directly from the budget constraint:

$$x_{H,t} = w_t h_t / p_{H,t} \tag{6}$$

To conclude the households block, as mentioned earlier, the consumption bundle x is given by the aggregation of energy and final good. Households optimize a CES consumption function, so with constant elasticity of substitution between energy/non-energy goods (ε_x). Moreover, consumption good (c_t) and the energy good (e_t) are weighted by household-specific distribution parameters ($a_{S,c}, a_{S,e}, a_{H,c}, a_{H,e}$), which is necessary to introduce heterogeneity in energy shares of total income[5]. Therefore, optimal consumptions $x_{S,t}$ and $x_{H,c}$, which resulted from the previous optimization, can be written as functions of energy and consumption goods as follow:

$$x_{S,t} = (a_{S,c}^{1/\varepsilon_x} c_{S,t}^{\varepsilon_x - 1/\varepsilon_x} + a_{S,e}^{1/\varepsilon_x} e_{S,t}^{\varepsilon_x - 1/\varepsilon_x})^{\varepsilon_x/\varepsilon_x - 1} \tag{7}$$

$$x_{H,t} = (a_{H,c}^{1/\varepsilon_x} c_{H,t}^{\varepsilon_x - 1/\varepsilon_x} + a_{H,e}^{1/\varepsilon_x} e_{H,t}^{\varepsilon_x - 1/\varepsilon_x})^{\varepsilon_x/\varepsilon - 1} \tag{8}$$

So agents maximize these consumption functions, subject to the following constraints, respectively:

$$p_{S,t}x_{S,t} = c_{S,t} + p_{e,t}e_{S,t} \tag{9}$$

$$p_{H,t}x_{H,t} = c_{H,t} + p_{e,t}e_{H,t} \tag{10}$$

[5]Following Känzig(2022)

Notice that the price of the consumption good is normalized to 1, while p_e is the price of energy. From this optimization problem, demand for energy and demand for the consumption good are obtained for the two households. Savers demand functions:

$$e_{S,t} = (\frac{p_{e,t}}{p_{S,t}})^{-\varepsilon_x} a_{S,e} x_{S,t} \tag{11}$$

$$c_{S,t} = (\frac{1}{p_{S,t}})^{-\varepsilon_x} a_{S,c} x_{S,t} \tag{12}$$

Hand-to-mouth demand functions:

$$e_{H,t} = (\frac{p_{e,t}}{p_{H,t}})^{-\varepsilon_x} a_{H,e} x_{H,t} \tag{13}$$

$$c_{H,t} = (\frac{1}{p_{H,t}})^{-\varepsilon_x} a_{H,c} x_{H,t} \tag{14}$$

Substituting (11) and (12) in the constraint (9), it is possible to get the expression for the price of consumption bundle of savers:

$$p_{S,t} = (a_{S,c} + a_{S,e} p_{e,t}^{1-\varepsilon_x})^{\frac{1}{1-\varepsilon_x}} \tag{15}$$

In the same way can be found the price of consumption bundle of Hand-to-mouth:

$$p_{H,t} = (a_{H,c} + a_{H,e} p_{e,t}^{1-\varepsilon_x})^{\frac{1}{1-\varepsilon_x}} \tag{16}$$

3.2 Production sector

The production block is constituted of two sectors. The energy production sector and the consumption goods sector. The first produces energy, which is sold to households and to final producers. The latter uses energy, labor, and capital to produce the final good and sell it to households. The two markets are assumed to be competitive.

3.2.1 Energy firm

The energy sector is competitive and can be expressed by a representative firm, which produces using labor ($h_{e,t}$) as a single input. $A_{e,t}$ is the total factor productivity (TFP), which is an exogenous variable in the model. The production function reads as follows:

$$e_t = A_{e,t} h_{e,t} \tag{17}$$

where e_t is energy supply.

The profit maximization problem of the energy producer will be:

$$\max_{h_{e,t}} p_{e,t}e_t - w_t h_{e,t} \tag{18}$$

subject to (17)

Computing the First Order Conditions of this problem with respect to $h_{e,t}$:

$A_{e,t} = w_t / p_{e,t}$

since $A_{e,t} = e_t / h_{e,t}$ from the production function, FOC can be rewritten as:

$$w_t / p_{e,t} = e_t / h_{e,t} \tag{19}$$

3.2.2 Consumption good firm

The final good sector is competitive and it can be expressed by a representative firm that uses energy, capital, and labor as inputs. The price of the final good is normalized to 1. The production function is a Cobb-Douglas and reads as follows:

$$y_t = k_t^{\alpha} e_{y,t}^{v} h_{y,t}^{1-\alpha-v} \tag{20}$$

The profit maximisation problem therefore will be:

$$\max_{k_t, e_{y,t}, h_{y,t}} y_t - r_t k_t - w_t h_{y,t} - p_e e_{y,t} \tag{21}$$

subject to (20)

Deriving the First Order Conditions for this problem:

w.r.t. k_t: $\alpha k_t^{\alpha-1} e_{y,t}^{v} h_{y,t}^{1-\alpha-v} - r_t = 0$

w.r.t. e_{y_t}: $v k_t^{\alpha} e_{y,t}^{v-1} h_{y,t}^{1-\alpha-v} - p_{e,t} = 0$

w.r.t. h_t: $(1-\alpha-v)k_t^{\alpha}e_{y,t}^{v}h_{y,t}^{-\alpha-v}-w_t=0$

The FOCs can be simplified, substituting back the production function. This leads to expressions for production inputs demands by the firm:

$$r_t=\alpha y_t/k_t \tag{22}$$

$$p_{e,t}=v y_t/e_{y,t} \tag{23}$$

$$w_t=(1-\alpha-v)y_t/h_{y,t} \tag{24}$$

3.3 Government

Let's introduce the government into the economy, assuming it runs a balance budget[6] fiscal policy so that tax revenues are equal to public expenditure (G_t)[7]. In particular, the government is taxing energy consumption at the rate τ_e. The budget constraint reads as follows:

$$G_t=\tau_e e_{x,t}p_{e,t} \tag{25}$$

where e_x is aggregate consumption of energy by the two household types. According to that, consumption constraints of households are modified to include the tax, so that p_e is multiplied by $(1+\tau_e)$. Consequently, also prices of bundles will change.

3.4 Aggregation and Equilibrium

Let's aggregate the following variables:
Capital: $(1-\lambda)k_{S,t}=k_t$
Investments: $(1-\lambda)i_{S,t}=i_t$
Total consumption: $x_t=\lambda x_{H,t}+(1-\lambda)x_{S,t}$
Final good consumption: $c_t=\lambda c_{H,t}+(1-\lambda)c_{S,t}$

[6]This is a restrictive assumption but allows to abstract from public debt and bond market modeling

[7]To keep the model as simple as possible, public expenditure is not considered in households utility functions. So there is no trade-off for the government in balancing taxes and public expenditure, since only the first affects households.

Energy consumption: $e_{x,t} = \lambda e_{H,t} + (1-\lambda)e_{S,t}$

Market clearing conditions are the following:
Labor market: $h_t = h_{y,t} + h_{e,t} = 1$
Energy market: $e_t = e_{y,t} + e_{x,t}$
Resource constraint : $x_t + i_t = y_t$

A general equilibrium of this economy is defined as a sequence of quantities $Q^H = \{x_t, x_{S,t}, x_{H,t}, e_{x,t}, e_{H,t}, e_{S,t}, c_{H,t}, c_{S,t}, c_t, i_t, k_{t+1}\}_{t=0}^{\infty}$, a sequence of quantities $Q^f = \{y_t, h_{y,t}, h_{e,t}, e_t, e_{y,t}\}_{t=0}^{\infty}$, a sequence of prices $P = \{\mu_t, w_t, r_t, p_{H,t}, p_{S,t}, p_{e,t}\}_{t=0}^{\infty}$ such that:

- Given P, Q^H solves households' optimisation problems.

- Given P, Q^S solves firms' optimisation problems.

- Given Q^H and Q^S, P clears all markets.

In this Appendix A is reported the full analytical derivation of the steady state.

3.5 Parameterisation

The parameters are set following the literature. According to Smets and Wouters's (2003) DSGE model for the EURO area, the capital returns to scale α is set equal to 0.30, and the depreciation rate δ is set equal to 0.025. β is set to 0.96 and the intertemporal elasticity of substitution (IES) $1/\sigma$ is equal to 1, which are both standard values in the macroeconomic literature. Concerning the IES however, Appendix D considers different scenarios with smaller and larger values since is a crucial parameter and there is no homogeneous empirical evidence on its estimation.
Following Känzig (2022), the energy income shares for the two types of agents, are set to match the energy expenditure shares of 9.5 percent for the Hand-to-mouth and 6.5 percent for the Savers. Also, energy returns to scale v are set to 0.07, following Känzig's (2022) estimation. The elasticity of substitution between energy and non-energy good is set equal to 0.21, according to Labandeira, Labeaga, and López-Otero (2017).

Moreover, since the analysis is on Belgium, the quota of Hand-to-mouth is calibrated according to ”Poor and wealthy hand-to-mouth households in Belgium” (2023) by Laurens Cherchye et al., which estimated that Hand-to-mouth correspond to 25% of the population in 2017. Therefore λ is set equal to 0.25. Table 1 resumes all parameter values.

Table 1: Parameter Values

Parameter	Value	Source
α	0.30	Smets and Wouters (2003)
δ	0.025	Smets and Wouters (2003)
ν	0.07	Kanzig(2022)
β	0.96	Macro literature
$1/\sigma$	1	Macro literature
a_h	9.5%	Kanzig (2022)
a_s	6.5%	Kanzig (2022)
ε_x	0.21	Labandeira, Labeaga, and López-Otero (2017)
λ	0.25	Cherchye et al. (2023)

Using those values for the parameters, the steady state formulas derived analytically and making a guess on capital, the steady state can be computed numerically on Dynare[8].

3.6 The shock in energy market

The beginning and the causes of the current energy crisis have been largely discussed and raised worries worldwide. The exceptional rise in prices of oil, gas, and electricity started in 2021, as one of the consequences of the COVID-19 pandemic. Indeed, the drastic fall of demand during the restrictions period and the consequent supply cut in the energy sector were followed by a rapid increase of demand once the emergency was over that was not matched as rapidly by the supply. The shortage of energy generated a general increase in prices, that was exacerbated by other international political events, in particular the outbreak of the war between Russia and Ukraine, since Russia is one of the main suppliers. Far from trying to analyze in detail the complicated system of factors that generate the crisis, and their respective roles, the objective of the analysis is to see the effect of such an increase in energy prices on inequality, so the focus

[8]Respective code is reported in Appendix F

will be on the demand side, rather than on the supply, on the effects rather than on the causes. To generate the increase in energy prices in the model, it will be introduced a negative TFP shock in the energy production sector. Indeed the COVID crisis and the increase in gas prices due to the Russian war, both led to an energy supply shortage that pushed the increase of energy prices. A negative TFP shock is a decrease of productivity in the production sector, which leads to a shrinkage of the supply and so, even if through a simplification, can quite well capture the consequences of the energy crisis.

Focusing in particular on the role of the Russian-Ukrainian war, many European countries quite rely on the import of gas from Russia, which is used also as an input to produce electricity by energy producers. Once the supply of gas was cut due to the war, energy firms faced a decrease in such input. An equivalent way to model this shock would have been to consider energy firms producing according to the following production function:
$e = F(K,g) = K^{\alpha} g^{1-\alpha}$
where g is an exogenous variable since is imported gas from abroad. Applying the negative shock on the exogenous variable g, it will lead to the same effect on the price of energy as the negative TFP shock. In other words, as explained in an article published by the Treasury Minister of France.[9]: "A disruption in the supply of imported gas could be seen as an exogenous decrease in TFP".

Moreover, there is a direct link between the other main cause of the energy price increase and TFP, as reported in "The impact of COVID-19 on potential output in the euro area", by Katalin Bodnár et al. [10]: "The coronavirus and containment measures negatively affect trend TFP through several channels. Supply chain disruption might be persistent and firms might need to find new suppliers, new transport routes or new locations of production. This might be exacerbated if the current pandemic increases protectionism and accelerates de-globalisation." This applies very well to the energy market, which is extremely globalized since many countries rely completely on energy imports from abroad.

So, even if not all, two of the main causes of the current energy crisis, led to an energy supply shortage, which can be captured by a negative TFP shock. The shock in the model is therefore applied on $A_{e,t}$ which is the total factor productivity of the energy sector.

[9] Benassy Quere (2022). Energy crisis: Europe by candlelight?
[10] Bodnár, K., et al. (2020). The impact of COVID-19 on potential output in the euro area

The shock on the exogenous variable $A_{e,t}$, consists in a decrease from 1, which is the steady state value, to 0.65. The magnitude of the shock is calibrated to obtain an increase in energy price of the same magnitude shown in Belgium data. In particular, according to CREG (Commission of Regulation for Gas and Electricity) data, in Belgium, prices increased by approximately 50% from December 2021 to January 2022[11]. The persistence of the shock is set to 20 periods, considering that energy prices had remained high for at least 20 months.

3.6.1 Simulation results

Using the function for simulation on Dynare (*simul*)[12] it is possible to see the effect of the negative TFP shock on the endogenous variables of the model. Figure 1 represents the trajectory of each variable after the shock, once their steady state had been normalized to zero to easy comparison[13].

The energy supply (e) plot, as expected, shows a decrease, due to the negative shock on productivity. On the other hand, the price of energy (p_e) sharply increases, as well as the prices of household consumption bundles, since the consumption bundle includes energy and the final good.

Looking at the production side, the shock impacts negatively the production of the consumption good. Indeed, given the energy shortage also demand for capital (k) and labor (h_y) by firms decreases, since inputs are not perfectly substitutes, and in general production (y) falls. Looking at households' responses, the effect is heterogeneous. Consumption of energy decreases for both agents (e_h and e_s) but it decreases more for Hand-to-mouth, and this is because Hand-to-mouth don't have savings to smooth consumption. The effect is exacerbated by the higher share of income spent on energy consumption. Moreover, since the elasticity of substitution between energy and non-energy good is low, also consumption of final good decreases (c_h) and so does total consumption (X_h) for Hand-to-mouth. For Savers the effect on consumption of final good and so total consumption is different because there is a substitution effect with savings. Indeed c_s and X_s initially increase because of the drop of the interest rate which leads to the choice of investing (invst) less and consuming more. Looking at the

[11](RA)2305/3 27 janvier 2022: Évolution des prix des différents produits sur le marché de détail par rapport aux prix de gros

[12]Respective Dynare code is in Appendix F; Notice that it is deterministic simulation

[13]In Appendix B are reported the most relevant variables plots separately, to see better the details.

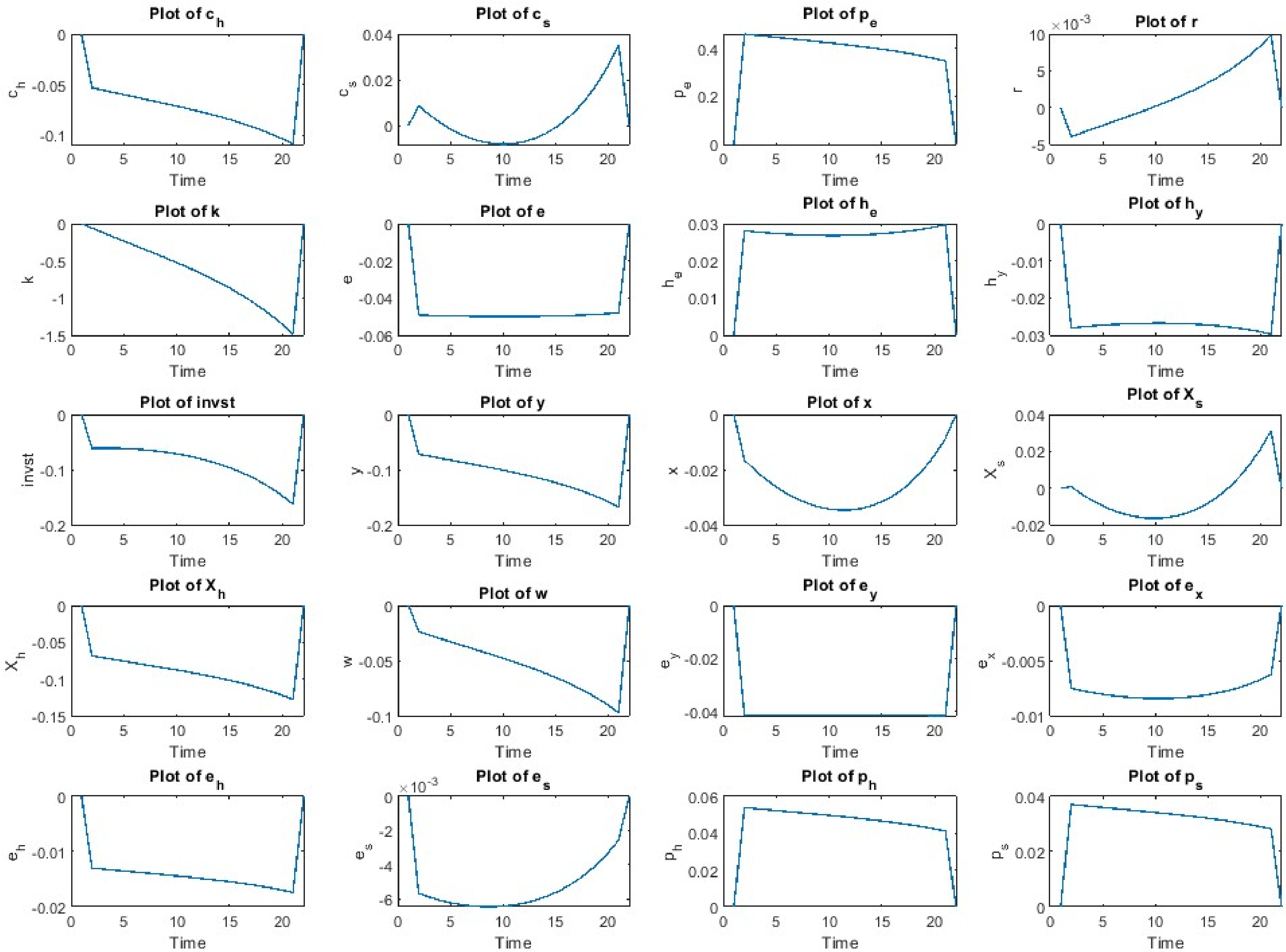

Figure 1: Trajectories of all endogenous variables of the model after the TFP shock. Steady state normalized to zero.

evolution over time, Hand-to-mouth consumption keeps decreasing even further until the end of the shock period, while Savers consumption (X_s) starts increasing again after a certain point, again due to the decrease in interest rate (r).

Overall, results are coherent with the literature on the topic, [14] the increase of energy prices hit harder low-income households, through two channels: the higher share of income spent in energy and the impossibility of smooth consumption through savings.

3.7 Fiscal policy

Let's see through the Heterogeneous Agents model the effect of the VAT cut implemented by the Belgian government. To do so it is introduced a second shock in the model so that the tax rate on energy is decreased from $\tau_e = 0.21$ to $\tau_e = 0.06$. The reform is implemented 5 periods after the energy shock happened, which is coherent with the fact that the VAT cut was introduced in March, so after 5 months from November 2021, when the sharp increase in prices was verified. In this way, the two scenarios can be compared: with government intervention (VAT cut) and without government intervention. This comparison can be seen in Figure 2, with trajectories of all endogenous variables for the two scenarios[15]. Focusing on the trajectory of Hand-to-mouth consumption (X_h), the VAT cut implies that the decrease in consumption of Hand-to-mouth is less severe. Accordingly, all endogenous variables of the model show an effect in the same direction due to the decrease in the tax. To be noticed is that since in the model shocks are implemented in a deterministic way, agents are forward-looking and can adapt behavior before the shock is realized. This explains why Savers and firms, which solve intertemporal problems, change their behavior in the VAT cut scenario before it is implemented (before period 5). To conclude, from the simulation results, the VAT cut implemented by the government seems effective in reducing the burden of the energy crises on households. Notice that the model structure assumes that the VAT cut is shifted completely on consumer prices. The empirical analysis, developed in the next sections, has the objective to assess whether this was the case in Belgium.

[14] Pieroni (2022), Kanzig (2022), Auclert et al (2022)

[15] In Appendix B are reported separately the most relevant plots

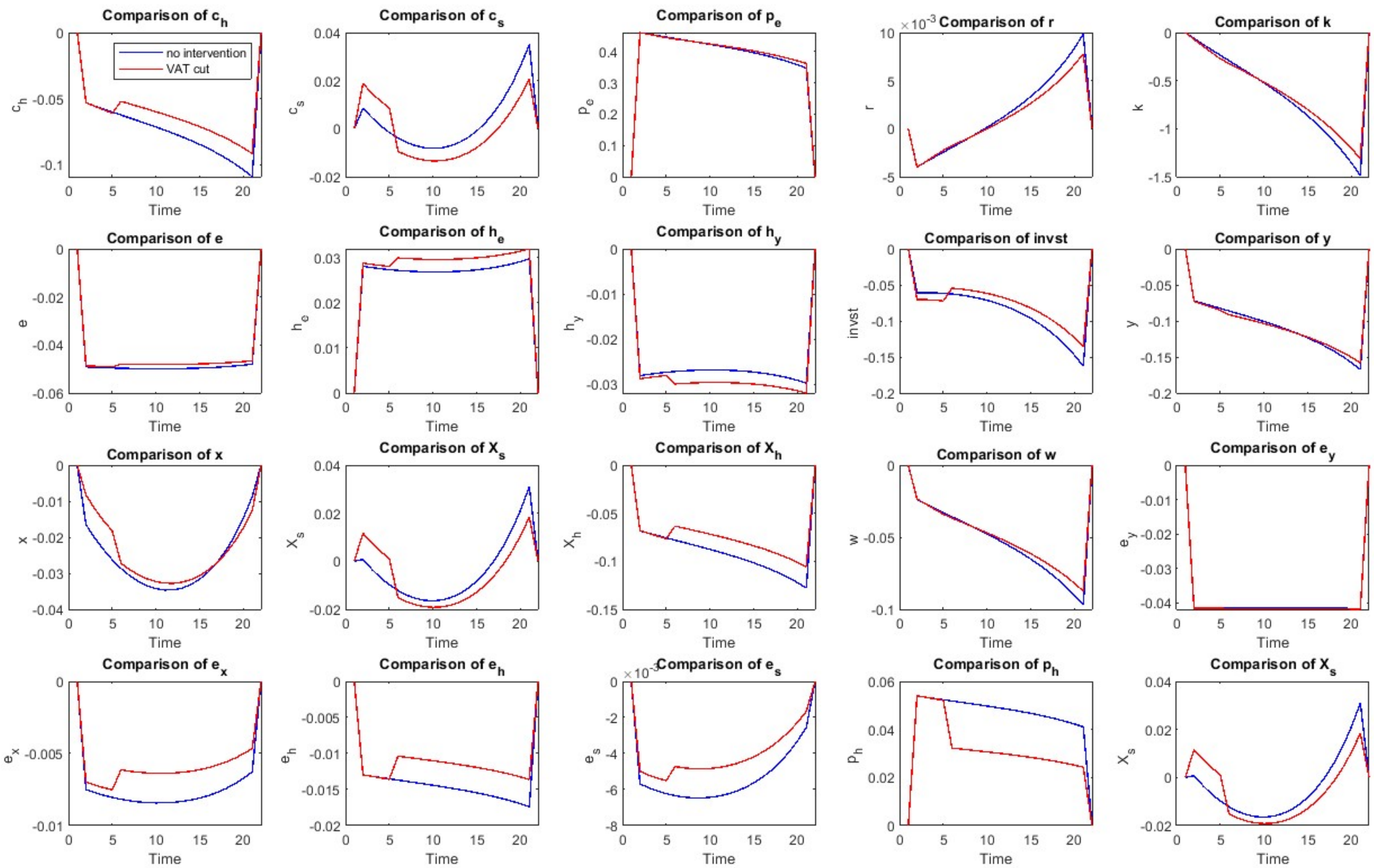

Figure 2: Trajectories of all endogenous variables of the model after the TFP shock in the scenario with VAT cut (red) and without (blue). Steady state is normalized to zero. The difference between the two scenarios is that in the second (red) in period 5 the VAT cut is implemented

4 Empirical Analysis

The empirical analysis of Belgian data has the twofold objective to look at the impact of the current energy crises on the country electricity market and to measure the pass-through of the VAT cut implemented in March 2022 to respond to such shock. The following subsections will first explain how Belgium's energy market works, then will give description of the data set available, next will discuss the empirical strategy and the role of the energy crisis and finally will implement the VAT cut pass-through estimation.

4.1 The energy market in Belgium

The Belgian electricity market is structured in four sectors. The Generation sector is a liberalized market, so in principle any entrepreneur can build a plant and start to produce electricity. In 2022 more than half of the electricity (47.3%) was produced by nuclear plants, 19.8% came from renewable sources, and 26.9% from gas[16]. The second sector is the Transmission System Operator (TSO), which consists in only one company appointed by the Energy Minister for 20 years. TSO firm has to transmit the electricity produced in the country and abroad from the transmission grid to the distribution network. This role is currently occupied by Elia. TSO prices have to be approved by CREG and are valid for four periods. Next, the Distribution System Operator (DSO) sector, consists in companies grouped by region, which transmit the electricity to final users. DSO prices are also regulated, since they have to be approved by regional institutions, which implies they may vary across regions. Finally, the retailers' sector is liberalized and constituted by companies that sell electricity to final consumers. Retailers either buy the electricity from a generator company or produce it themselves. In the latter case, the generator and the retailer are owned by the same company, which is quite common. The Belgian electricity market is indeed structured according to unbundling ownership model, which means that the producer's and retailers' sectors must be separated from TSO and DSO sectors, through independence requirements set by law [17].

The energy bill that final consumers receive is therefore given by the sum of many components: producer prices, DSO and TSO charges, retailer prices, taxes, and other surcharges. To be noticed that since DSO and TSO prices are fully regulated, VAT

[16]"Belgium's 2022 electricity mix: the increase in renewable energy and availability of nuclear power plants kept exports high", press release Elia Group (Jan 2023)

[17]Hindriks and Serse (2022)

applies automatically. On the other hand, producers and retailers can freely set prices according to the competitive market forces. For this reason is interesting to look at these price components, that are not regulated, when studying the pass-through of the VAT cut. Moreover, the price is a two-part tariff: one part is a fixed fee, to be paid independently by the amount of energy consumed and the other part is a flat rate for each kWh consumed. There are two types of contracts: with fixed rate and with variable rate. For the first type, the price for kWh does not change during the contract period, while for the latter the rate is adjusted according to an indexation formula that can be updated each month.

4.2 Data

Data are provided by the Commission de Régulation de l'électricité et du Gas (CREG). Prices are available for gas and electricity and include all providers and all types of contracts, offered to both households and firms. The price series are monthly, and cover the period from January 2014 to December 2022 included.
The analysis will center on Luminus[18], one of the key electricity providers, which held a market share of approximately 7% in Brussels, 24% in Flanders, and 24% in Wallonia in 2022 [19]. The study will consider two contract types offered by Luminus: fixed-rate contracts and variable-rate contracts. To represent these contract types, the most frequently utilized products from Luminus will be selected[20], encompassing both the firm and household versions. Consequently, a total of four price series will be extracted from the dataset, allowing for a comprehensive examination of pricing trends.

Moreover, it is not possible to follow the same products for the whole period, since during those years some products stopped being offered and new ones have been introduced. For this reason, the analysis focuses on the period that goes from January 2017 until July 2022. During this time indeed, is possible to track the prices of the contracts that are resumed in Table 2, avoiding any discontinuity.

Prices data are expressed in their different components: the fixed charge, the price per kWh, the green quota, which is a charge asked consumers to contribute to the

[18]The choice of focusing only on Luminus, which is the second main provider, is due to the fact that the first, Engie Electrabel, stopped offering any fixed contracts after March 2022 and is of interest for the research to follow both types of products

[19]CREG website (https://www.creg.be/fr/consommateurs/le-marche-de-lenergie/parts-de-marche-des-fournisseurs-denergie)

[20]This was assessed by looking at data on the number of contracts subscription per product, also available at CREG

Table 2: Luminus products selected for the analysis

Contract name	Contract type
Household contracts	
ACTIF+	Variable
Begreen	Fixed
Firm contracts	
ACTIF+ PRO	Variable
Begreen PRO	Fixed

process toward renewable energy, and the VAT rate applied. Notice that the VAT does not apply to firm products, and that's why firm prices (VAT exclusive) are a good control group for household prices (VAT inclusive). Moreover, for each contract are provided information about duration, end of contract date, and when and until when that product was on the market. For variable contracts coefficients and indexes of the indexation formula are available. All the following analysis will use price for kWh component but can be easily extended to other components and full price [21].

4.2.1 Descriptive statistics

Table 3 reports some descriptive statistics of the data set. Such statistics are computed for the price per kWh component so the measurement unit is euro cents. It has to be noticed that households' product prices are on average higher than firms' ones. This difference is due also to the fact that VAT applies only to the first and not to the latter. Comparing minimum and maximum values can be seen clearly how prices reached very high values, that are very distant from the mean. This is explained by the fact that such observations correspond to energy crisis months, which are few compared to the total number of months included in the sample. Lastly, it can be noticed that on average variable contract prices are lower than fixed contract prices.

[21] The reason why the analysis is not done using the full price of energy is that DSO and TSO prices for 2021 and 2022 were not available yet in the database at the time of the research

Table 3: Descriptive statistics of price per kWh

Contract Type	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Standard Dev.
All contracts	5.180	7.160	7.932	9.985	9.803	38.490	6.10081
Household contracts	6.700	7.879	8.835	10.735	10.535	37.130	5.992586
Firms contracts	5.180	6.791	7.286	9.235	8.060	38.490	6.137968
Variable contracts	6.242	7.063	7.626	8.454	8.427	17.628	2.627644
Fixed contracts	5.180	7.420	8.905	11.516	10.617	38.490	7.943143

*All contracts refers to the four products considered: Begreen, Begreen PRO, Actif + and Actif + PRO

4.2.2 Variable contracts indexation formula

This paragraph will explain in some more detail how variable contracts work and how the price is determined. Variable contracts follow an indexation formula so that the price is adjusted depending on the energy market conditions. In particular, the formula reads as follows:

$$A + (Index * B + C) * kWh \tag{26}$$

where A is a subscription, which covers, among other things, customer maintenance costs and underlying administration; Index is the indexation parameter which is an arithmetic average of the daily closing prices for delivery in the Belgian electricity market. B, the coefficient by which the indexation parameter is multiplied, is as a margin on the indexation parameter. Finally, C is the markup, also known as the supplier's profit margin, that is added to the consumption-related portion. The link between the evolution of the market price of energy, captured by Index, and the price that households pay as consumers for their variable product, is not that immediate. On one hand, depending on the indexation parameter, there is a time lag between the moment of quotations on wholesale markets and the moment these quotations are processed in the indexation parameter. This can range from a few weeks to several months, and in exceptional cases, even several years. On the other hand, for example, a 15% decrease in wholesale markets does not necessarily mean a 15% decrease in the energy component. [22] The subscription, the margin on the indexation parameter, and especially the mark-up, which, together with the indexation parameter, make up the energy component, have a smoothing effect on the evolution of the indexation parameter. Since the beginning of 2021 and during 2022, many products have experienced significant

[22] CREG Rapport (RA)2305/11

increases in their subscription fees, coefficient, and markup. Both the coefficient and the markup are added by suppliers to cover certain costs, but they also include profit margins. Such increases vary from one supplier to another and even from one product to another within the same supplier. Focusing on the product of interest, ACTIF + by Luminus, the markup was kept stable from 2013 until November 2021, when it started to be changed almost each month until the end of 2022. This change was visible in the data, that from November 2021 reported more than one observation of price for each month. Indeed, the markup was updated for new customers but previous contracts with the old markup value were still on the market and so had different prices. The markup increase can be seen as a way for Luminus to smooth the sharp increase in costs further than what is allowed through the market indexes. The increase in markup is clearly visible in Figure 3, taken from CREG Report "Évolution des prix en décembre 2022 des différents produits sur le marché de détail par rapport aux prix de gros" (Rapport (RA)2305/11). As explained in this report, due to the increase in coefficients and mark-ups (represented by B and C), the annual bill for consumers has increased by approximately €100 to €150 on average. This has nothing to do with the very high level of prices in the electricity and natural gas markets since 2021 (represented by Index). When selecting the price series to follow, it was necessary to choose only one observation per month, so to choose between the different prices generated by the different markups, starting from the end of 2021. Taking the last updated prices would reflect better the current energy price in the market. However, since markup was changed differently between firms and household products, the two series showed divergence. For this reason, it was chosen to keep following the product with the initial markup of 2013 and not the ones with the updated markup. In Appendix A, some descriptive statistics on variable contracts better show such differences and justify this choice.

It is important to notice that such upward manipulation of the indexation formula parameters is one of the ways through which providers responded to increase of costs during the energy crisis. For this reason CREG is conducting a general investigation by requesting more details and explanations from all suppliers regarding the evolution of these indexation formula parameters. Another effect was that most companies stopped offering fixed contract, because otherwise they would have the risk of encountering losses in a period of high cost volatility.

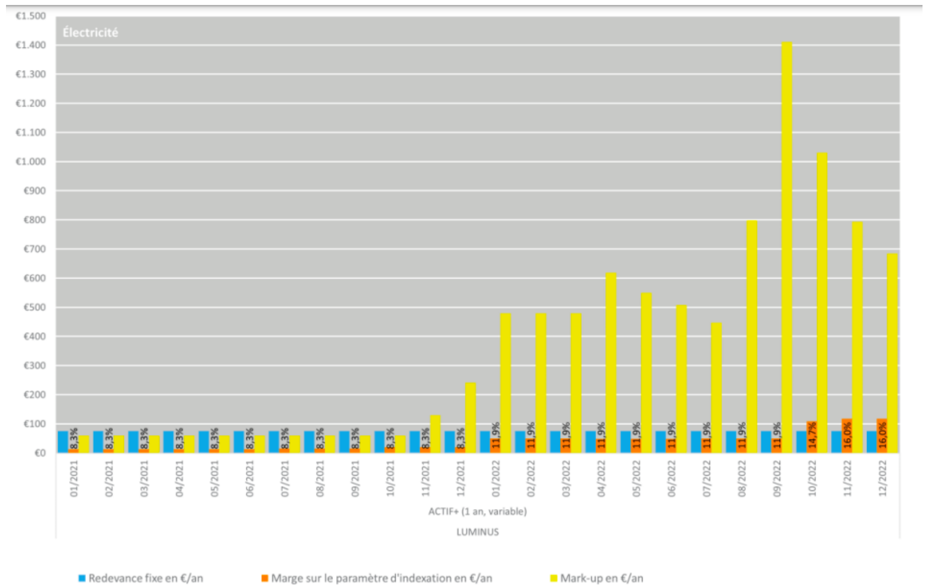

Figure 3: Luminus ACTIF+ mark up increase from CREG Rapport (RA)2305/11

4.3 Empirical strategy

Through the data set it is possible to estimate the effect of the VAT cut from 21% to 6%, implemented by the government in March 2022, as a response to energy crises. The analysis of the VAT incidence will be an extension for 2017-2023 of Serse and Hindriks (2022), which measured it in the period 2013-16. Indeed, in March 2014 the VAT on electricity was reduced to 6% and then it was taken back to its pre-reform level of 21% in August 2015. The empirical strategy consists in applying a difference-in-difference analysis, using as control group energy prices for firms, which do not pay the VAT and so are not affected by the policy. To be able to apply dif-in-dif (DiD) methods a crucial assumption must hold: the trends of the treatment group and control group should be parallel before and after the treatment period.

Let's check the price trend of the treatment group and control group. Figure 4[23] is a plot of average prices between the two products (fixed and variable contracts) respectively for firms and for households. As shown in the graph, household prices are always higher than firm prices and follow a parallel trend. Then in March 2022 can be seen the effect of the VAT cut, since household prices dropped, as shown in Figure 5,

[23]These graphs are realized on R by the author; respective codes can be found in Appendix G

which is a zoom on the last months of the time series. As the two graphs show, parallel trend assumption necessary to perform a DiD analysis is respected.

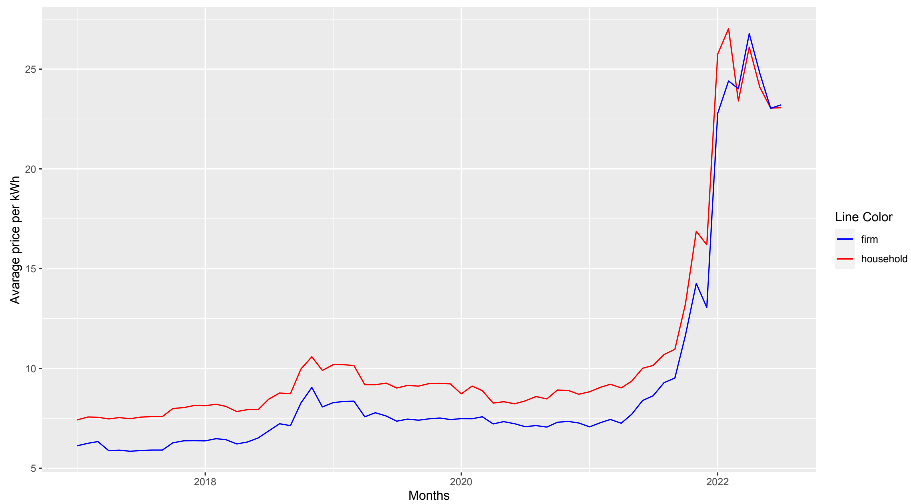

Figure 4: Luminus BEGREEN and ACTIF + products average electricity prices per kWh in euro cents, for firms (blue) and households (red)

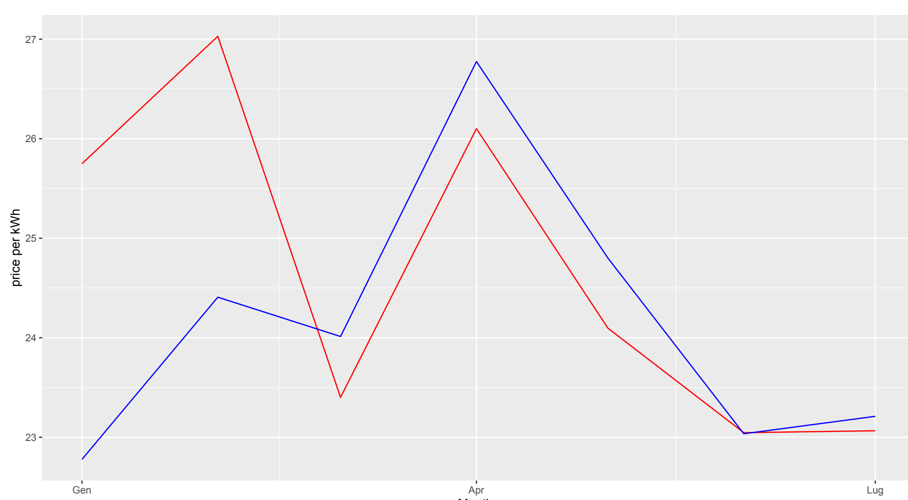

Figure 5: Luminus BEGREEN and ACTIF+ products average electricity prices per kWh in euro cents, for firms (blue) and households (red); Zoom on the VAT cut months (March - July 2022)

However, it has to be notice that to perform OLS estimation of the coefficients other assumptions must old. In particular, exogeneity assumption rise some concern in this context. Indeed, the situation is very different from the one analyzed by Hindrinks and Serse in 2014. At that time, the VAT cut was a purely exogenous reform since was driven by political motives that were not related to the energy market. On the other hand, the current energy crises and the sharp price increase, represent the reason why the government decided to implement a VAT cut in March 2022. Given this, some concerns about the reliability of the DiD results can be raised. For this reason, the next section will first replicate the estimation of the VAT 2014 pass-through and next will perform the analysis for 2022 reform. In this way will be possible to disentangle any effect of plausible endogeneity during the second VAT cut.

4.4 VAT cut of 2014

To replicate the study of Hindriks and Serse (2022) it is available a data set that has observations for the same products that were followed in such analysis. However, the data set is not the same since are missing observations for the year 2013. For this reason, results are not expected to be the same. Instead, this replication has to be interpreted as a mean to check for endogeneity effects that can be assessed by the comparison between estimates for 2014 and estimates for 2022.

Taking the prices from January 2014 until December 2016 for the same four products by Luminus and Engie Electrabel selected in Hindriks and Serse (2022) [24], Figure 6 shows that the parallel trend is respected.

From the graph can be clearly seen that prices follow a parallel trend before and after the reform. Moreover, has to be noticed that in those years prices were quite stable (always in a range of 4-8 euro cents per kWh). This is not comparable with what is observed during the energy crisis when prices went up to five times their usual values. This stable trend observed in the 2014-16 period proves the exogeneity of the reform, which was not driven by energy market changes.

The linear regression model to measure the pass-through reads as follows:

$$Ln(P)_{ijt} = \beta_0 + \beta_1 HH_j + \beta_2 VAT_{cut14} + \beta_3 ln(1+\tau) + \varepsilon_{ijt} \quad (27)$$

The dependent variable is the natural logarithm of prices per kWh per each prod-

[24] By Luminus: Click (fixed) and ACTIF+ (variable); by Engie Electrabel Easy Indexed and Easy fixed; all in their version for household and for firms

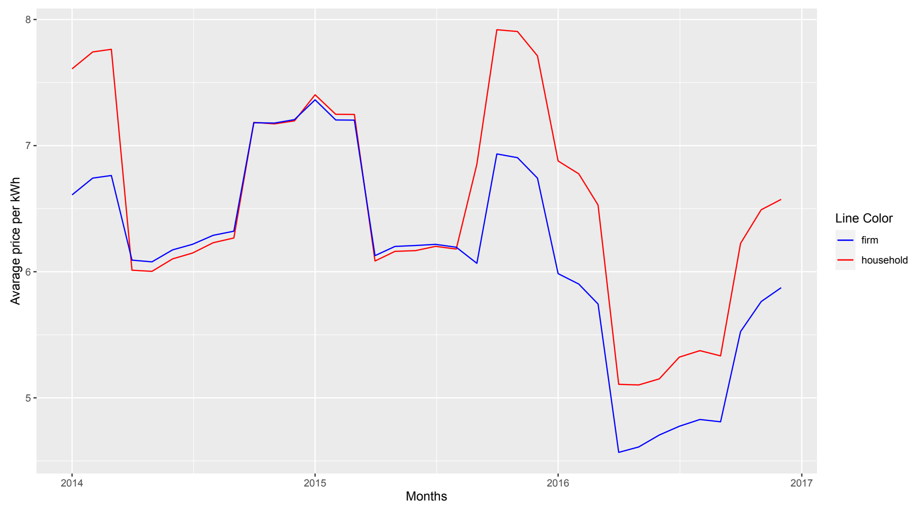

Figure 6: Luminus and Engie Electrabel fixed and variable products average electricity prices per kWh in euro cents, for firms (red) and households (blue); VAT cut period goes from March 2014 until August 2015

uct i in each month t for each household type j. As specified before, household prices are VAT-inclusive. HH is a dummy variable that takes a value of 1 if the price refers to a product for households (treatment group) and 0 if is a product for firms (control group). Therefore coefficient β_1 expresses the average difference between firm prices and household prices. The regressor VAT_{cut14} is a dummy variable that indicates if observations are or are not in a period of VAT cut; so it assumes value 1 during the months of the first reform. Consequently, β_2 captures the evolution of electricity prices for firms during the period of VAT cut, while the intercept β_0 represents the average price for firms. Finally, the last regressor is the natural log of the VAT multiplicator $1+\tau$ applied in each month, which can be either 1.21 or 1.06 and is always 1 for firms. So that β_3 is the coefficient of interest since it represents the pass-through rate of the tax. To be noticed is that $ln(1+\tau)$ is a transformation of the standard treatment regressor. Indeed, in standard DiD models the treatment regressor is given by the product of the two dummies variables. Here instead, following Hindriks and Serse (2022), this regressor is transformed to measure directly the pass-through. In Appendix B can be found the same analysis conducted using standard DiD regression and the explanation of the transformation.

Running this regression[25] are obtained results reported in Table 4.

Table 4: Coefficients

	Estimate	Std. Error	t value	p-value
(Intercept)	1.11743	0.20911	5.344	1.59e-07 ***
HH	-0.04025	0.03664	-1.099	0.272685
VAT_{cut14}	-0.16532	0.02267	-7.291	1.88e-12 ***
$ln(1+\tau)$	0.75751	0.21550	3.515	0.000494 ***

As shown in the table the pass-through coefficient is significant and indicate an under-shifting (75%) of the VAT cut. Also, the VAT_{cut} coefficient is significant and negative, indicating that for firm prices in the months of VAT cut had decreased.

4.5 VAT cut of 2022

Let's now move to the study of the pass-through of the 2022 VAT cut. We have already seen that the parallel trend assumption is respected. Is possible to apply the same linear regression as follows[26]:

$$Ln(P)_{ijt} = \beta_0 + \beta_1 HH_j + \beta_2 VAT_{cut22} + \beta_3 ln(1+\tau) + \varepsilon_{ijt} \tag{28}$$

Results of this regression are reported in Table 5.

Table 5: Coefficients

	Estimate	Std. Error	t value	p value
(Intercept)	0.68077	0.90530	0.752	0.453
HH	-0.09301	0.18239	-0.510	0.611
VAT_{cut22}	1.08641	0.09545	11.382	<2e-16 ***
$ln(1+\tau)$	1.34830	0.89990	1.498	0.135

As Table 5 shows, the pass-through coefficient indicates an over-shifting. However, estimates are not significant. Also running the analysis for fixed contracts and variable contracts separately, lead to the same results. There are several reasons why this may happen. Also, VAT_{cut22} significant positive coefficient indicates that electricity price for firms had remarkably increased during the VAT cut period. This confirms confirm the evidence visible in the Figure 4, that reform is not exogeneous. Both this issue will be discussed in the next section.

[25]The respective R code can be found in Appendix G
[26]The respective R code can be found in Appendix G

4.6 Significance of results

Sample size

The sample size may be too small to have significant estimates. Indeed, the number of observations consists of 4 cross-sectional units, since two products are followed, one fixed and one variable in their versions for firm and household. These units are observed across time, so the time series sample size is 67 since there are monthly observations for five years plus 7 months of 2022; However, most of the sample is from months before the VAT cut, and observations during the treatment are only 5 (from March to July). In the previous study of the VAT cut of 2014, 8 products were followed instead of 4. Moreover, the months of the treatment period were considerably more (17). To try to improve significance, and to check whether the sample size is part of the problem, observations of August and September will be added to the sample. To be able to do so is necessary to change the fixed product since BEGREEN was not offered anymore in those months. Therefore, August and September observations correspond to the prices of COMFY, which was a new product introduced to substitute Begreen. The results of this regression are resumed in Table 6.

Table 6: Coefficients

	Estimate	Std. Error	t value	p value
(Intercept)	0.71527	0.84373	0.848	0.397
HH	-0.08576	0.16736	-0.512	0.609
VAT_{cut22}	1.17866	0.08877	13.278	<2e-16 ***
$ln(1+\tau)$	1.31380	0.83691	1.570	0.118

As it can be seen from the reduction of the p-values, significance is improving for all coefficients. In particular, the p-value of pass-through decreases from 0.135 to 0.118, but is still not enough to be able to reach significance of results. This could mean that if more observations were available during the VAT cut period, for next months of 2022 and for 2023, sample size increase could improve precision of estimates.

Exogeneity of the reform

The second issue in the analysis, as anticipated in the paragraph on empirical strategy (4.3), is exogeneity. Indeed, the context of the VAT cut of 2022 indicates that the reform was not exogenous. The government indeed explicitly declared that the VAT cut was a response to the energy crisis and the increase in electricity costs. It was intended as a way to reduce the burden on households and so is strongly correlated with the sharp increase in prices observed in such months. An additional confirmation comes from the official declaration of the government, that can be read in the Arrêté royal [27]. Indeed, the regression coefficient VAT_{cut} is positive. This indicates that being in the months of the reform has a positive effect on electricity prices of firms, and it is because those months are also the months of the crisis. The implication is that the assumption of exogeneity, necessary to perform OLS analysis, does not hold, and so, as expected, this has consequences on the estimation and the significance of the regression coefficients.

Price volatility

Lastly, during the VAT cut period, prices were highly volatile. As can be seen comparing the two graphs of the two VAT cuts, in 2014 prices were quite stable. Instead in the months during which the second VAT cut took place prices were oscillating sharply: for instance, they kept increasing right after the VAT cut and then decreased again. Price volatility also may have an impact on the reliability of the estimation of the pass-through coefficient. Indeed, the explanatory power of a the VAT cut variable is limited when the variance of the dependent variable is high.

5 Conclusions

This study investigates the current energy crisis in Europe and its implications for inequality. Specifically, it aims to assess the unequal impact of increasing energy prices on different income groups and evaluate the effectiveness of a VAT cut as a fiscal policy response to mitigate the consequences of the crisis. To accomplish this, a General Equilibrium model is constructed, incorporating heterogeneous agents, the energy sector, and government intervention. The findings demonstrate that financially constrained households experience a more pronounced burden from the shock, while the implemented fiscal policy proves effective in alleviating such an impact. Furthermore, an empirical analysis is conducted to examine the VAT incidence on energy prices, aiming to measure the efficacy of the policy implemented in Belgium in March 2022 to respond to the crisis. The results indicate an over-shifting of the tax, affirming the successful implementation of the policy. However, the limited sample size and the endogeneity of the reform warrants further investigation and data collection to confirm the conclusions drawn on the pass-through rate estimation.

[27] Arrêté royal modifiant les arrêtés royaux nos 4 et 20 en matière de taxe sur la valeur ajoutée en ce qui concerne la diminution du taux de la taxe sur la valeur ajoutée relatif à la livraison d'électricité, de gaz naturel et de chaleur via des réseaux de chaleur dans le cadre de contrats résidentiels"Translation from Deeple: "Royal Decree amending Royal Decrees Nos. 4 and 20 on value-added tax as regards the reduction in the rate of value-added tax on the supply of electricity, natural gas and heat via heat networks under residential contracts

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