The Macroeconomic Effects of the Energy Price Cap: An Evaluation Conducted Using the ThreeME Multisectoral Model

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Abstract – The energy crisis that struck Europe in 2021 as the world bounced back from COVID, and amplified by the Russian invasion of Ukraine, led to a sharp increase in energy prices, particularly gas prices. In this context, European nations implemented emergency measures to protect households' purchasing power and the competitiveness of their businesses. France chose to mitigate energy price rises by implementing a price cap. Making use of a computable general equilibrium model, we explicitly simulate the divergent trajectories of energy prices with and without this price cap. Our results show that the budgetary cost of this measure was lower than initially expected, and while the macroeconomic impact was also relatively small, it did nonetheless preserve household purchasing power.

JEL: C68, E64, E65, Q43, Q48
Keywords: macroeconomics, energy crisis, energy price cap, public policy evaluation

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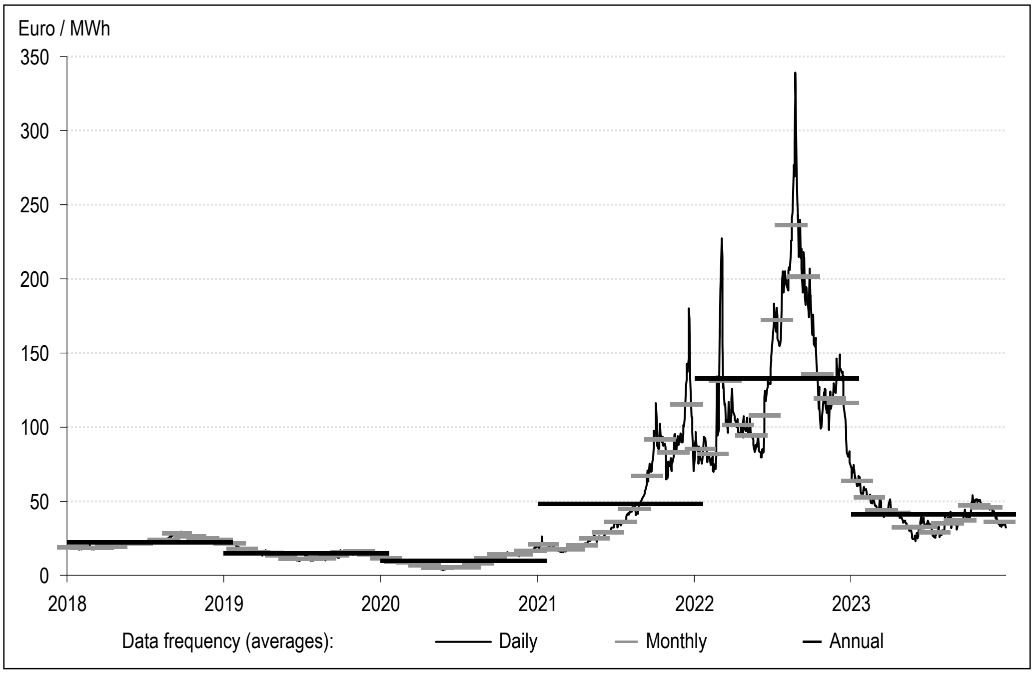
The Russian invasion of Ukraine in February 2022 exacerbated a major energy crisis for the European Union, which had first emerged in September 2021 in the wake of the post-COVID rebound in international demand. Although European countries were quick to condemn Russia and introduce economic sanctions in February 2022, particularly on energy products such as coal and oil, their heavy dependency on Russian gas for energy supplies posed a major risk to the stability of their energy networks and the continued functioning of their economies.

In spite of the uncertainties expressed in 2022 with regard to the capacity of Europe's energy system to withstand the sudden withdrawal of Russian energy imports, the system has in fact demonstrated its resilience. As noted by the International Energy Agency (IEA, 2023), various factors contributed to a 3% reduction in global energy consumption in 2022 compared with the previous year. These included a mild winter in Europe, along with conscious efforts to reduce energy consumption.

Another important aspect of the crisis is the way in which it has amplified the operating fluctuations of European electricity markets, particularly for intraday and day-ahead transactions. On the futures market, exchanges between energy buyers and producers are agreed in advance and the prices and quantities are fixed. Such transactions generally involve power plants which can be controlled, and the prices recorded are generally lower than those seen on the day-ahead and intraday markets. The latter markets are constantly balancing supply against demand, and sale and purchase agreements are made for fixed periods of time. The equilibrium price is also known as the spot price. It corresponds to the marginal cost of the most recent production unit put into service, following the *merit order* principle (power stations are utilised in a specific order based on their respective production costs: the cheapest sources are prioritised, then progressively more expensive sources are used until the demand is satisfied), with all producers being paid at this marginal price. To the extent that gas-fired power plants (and, to a lesser extent, fuel oil plants) can be controlled, and thus serve to guarantee the stability of the network, the spot prices for gas are often used as the benchmark for setting electricity prices, with the Dutch TTF regarded as the reference market (Figure I).

Between December 2020 and December 2021, the price of importing energy into the Eurozone more than doubled, driving inflation up in European nations. Average inflation in EU member states was 9.2% in 2022, a threefold increase on the preceding year. France was an exception to the rule, with a rate of inflation of 5.9%, while the rate rose to 8.3% in Spain, 8.7% in Germany and Italy, 11.6% in the Netherlands and 13.2% in Poland.

Figure I – **Variations in the Dutch TTF index for gas spot prices**



Note: The horizontal lines represent the annual (black) and monthly (light grey) averages.
Source: ICE.

With regard to the situation in France, between Q2 2021 and Q2 2022, rising energy prices contributed 3.1 percentage points (pp) to the total rate of inflation in France, which stood at 5.3%. The introduction of a *price cap* ("*Bouclier tarifaire*" in French) limiting price rises for electricity and gas to 4% made it possible to reduce energy inflation from 54.2% to 28.5% for households (and 50.3% to 20.3% for businesses) (Bourgeois & Lafrogne-Joussier, 2022). The energy price cap operates on the principle that the national government will subsidise the difference between the capped price paid by consumers and the price charged by suppliers, determined by market conditions. As such, while it maintains inflation at the desired level, the cost of this measure for the government depends primarily on market prices. Among the measures adopted by European nations, France's decision to maintain prices at a certain level was relatively unusual (Sgaravatti *et al.*, 2023); most other EU member states opted for transfer mechanisms.

The purpose of this study is to better understand the macroeconomic effects of the energy price cap by explicitly representing the price structure, from wholesale prices to consumer prices, within the macroeconomic context. We conducted this evaluation with the help of a computable general equilibrium model called ThreeME, combined with a detailed calibration of electricity and gas prices. An alternative approach to evaluating the macroeconomic effects of the energy price cap in France (Langot *et al.,* 2023) has been proposed, based on a *Heterogenous Agents Neo Keynesian* (HANK) model. The authors of that study estimate that the price cap served to reduce inflation by 1.1 pp in 2022 and 1.8 pp in 2023, while mitigating the decline in GDP growth by 1.1 pp to keep it at 2.9 pp in 2022, and by 0.9 pp to keep it at 1pp in 2023, all at a fiscal cost of approximately 2% of GDP.

These two approaches reveal themselves to be more complementary than contradictory, to the extent that they use different models with different theoretical frameworks and refinement techniques, thus providing multiple perspectives on the same issue. The HANK model, for example, provides an integrated representation of household heterogeneity, thus enabling us to assess the redistributive dimension of the policy, a possibility not offered by the ThreeME model since it focuses on a single representative household. On the other hand, using a detailed multisectoral model enables us to establish an explicit representation of price trends for different energy products (gas and electricity). In the calculations made using the HANK model, the price cap is regarded as an additional spike in public spending with an impact on an economy comprising both a composite product and an energy product: it is based on the forecasts issued by the French government in the Draft Budget Bill for 2023, presented to the Parliament in September 2022 and passed into law in December 2022. One of the limitations inherent to this approach is that it relies upon the government's estimates for the expected fiscal cost of the measure, estimates which were calculated when the spot price was at its peak (cf. Figure I) and thus fail to reflect the waning of prices observed post-26 August 2022. Our study seeks to further explore this matter, incorporating an updated price estimate into the macroeconomic framework.

Section 1 offers some context on the French energy market and the data used to calibrate the model. In Section 2, we detail the modelling framework we used to analyse the energy price cap policy. In Section 3 we present our results, which are further discussed in Section 4, before offering a brief conclusion.

1. Political Context

1.1. The French System: A Two-Speed Energy Market

Formerly a state-controlled monopoly, the business of supplying gas and electricity was opened up to new actors in 2007, with a view to creating a competitive marketplace. Although the market is now open, electricity consumers in France can still choose between market prices and regulated prices. This was also true of gas until July 2023, when the two-speed system came to an end. The regulated price scheme available to consumers is operated by France's historic energy supplier, with prices set by the Energy Regulation Commission *(Commission de régulation de l'énergie,* or CRE), an independent body not under government control. The regulated energy price comprises three components: fair remuneration for the energy supplier (dependent upon wholesale prices), distribution and network costs, and taxes (VAT and other forms of excise). Each of these components accounts for around a third of the price. Prices are set annually for electricity, and monthly for gas. For electricity prices, this means that consumers are guaranteed a stable price for the entire year. For suppliers, if wholesale prices vary considerably over the course of year, to the extent that the regulated price is no longer enough to cover their costs, then a price supplement will be added for the subsequent period so that they may recoup those costs. The more frequent adjustment of gas prices, meanwhile, creates greater volatility for consumers, but allows for better adjustment to fluctuations in wholesale prices. Due to the frequency with which prices are adjusted, the abolition of regulated gas prices in July 2023 has not significantly impacted the gas price trend.

The gas price deals available on the market are generally based upon the observed regulated prices. Often, households sign up to contracts which guarantee them gas at a price several percent below the regulated price for a fixed period of time, after which time the price is recalculated with reference to current market conditions. Alternative suppliers cover their costs by anticipating wholesale prices on the futures market, and optimising their contract prices. As such, at any given moment, average prices should be more or less aligned with the regulated price. Due to the unexpected spike in wholesale prices, some contracts turned out to be unprofitable because they were locked into low prices. Conversely, new contracts signed at market prices during the price surge would have involved significant price increases. Households signed up to market price contracts currently represent approximately 30% of the overall market; the vast majority of households prefer to stick with regulated price contracts.

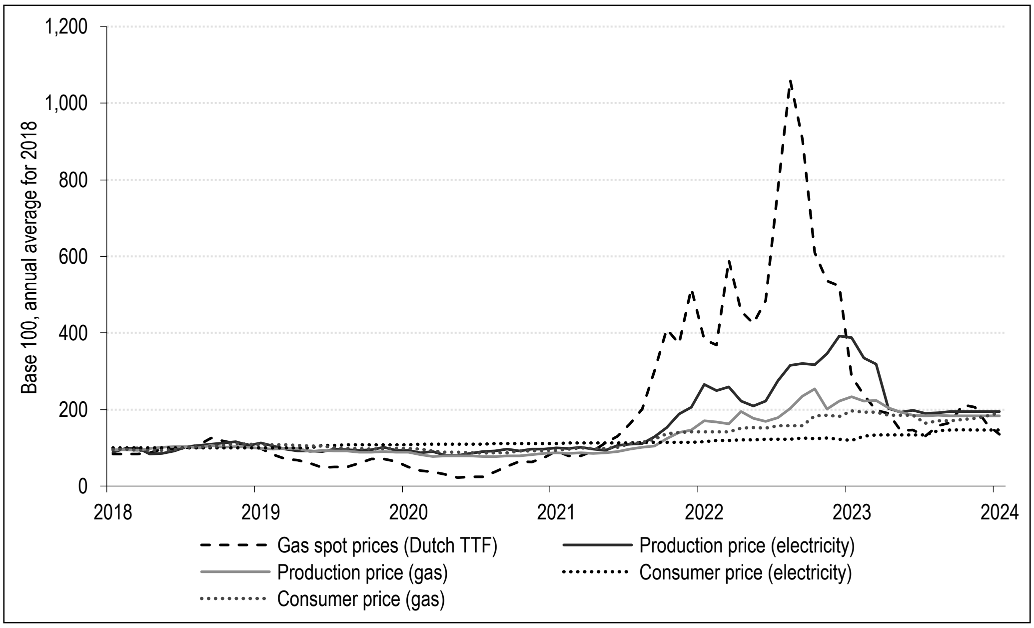
On account of this system, consumer prices for energy in France usually see relatively modest fluctuations (Figure II), because energy prices tend to be anchored by the regulated price. The repercussions of variations in wholesale energy prices in France are among the weakest in Europe, particularly for electricity (Ari *et al.,* 2022). The same goes for the contribution of energy prices to headline inflation in France, compared with other European nations.

1.2. Regulating Energy Prices in Times of Crisis: The Price Cap

In the second half of 2021, wholesale gas prices saw a series of major spikes (fluctuations in the average daily price were as much as ten times greater than pre-crisis levels), having lingered at historically low levels in 2020 in the midst of the COVID-19 pandemic. As economies rebounded rapidly from the crisis, especially in Asia, and Europe experienced a cold winter, the demand pressure for natural gas led to a first significant increase in wholesale prices. This energy inflation crisis was exacerbated by the second Russian invasion of Ukraine, starting 24 February 2022. When the European Union declared an embargo on Russian gas, with great difficulty on account of the severe gas dependency of some member states, the cost of alternatives (primarily liquefied petroleum gas, LPG) increased further still. On the Dutch natural gas futures market (Dutch TTF), the benchmark for wholesale gas and electricity prices in Europe, intraday prices exceeded the 1,000 euro/MWh threshold on several occasions.

In France, where regulated gas prices are recalculated monthly, the method employed by the CRE

Figure II – **Monthly indices for gas and electricity prices**



Note: The dotted lines correspond to the annual averages.
Sources: ICE, INSEE.

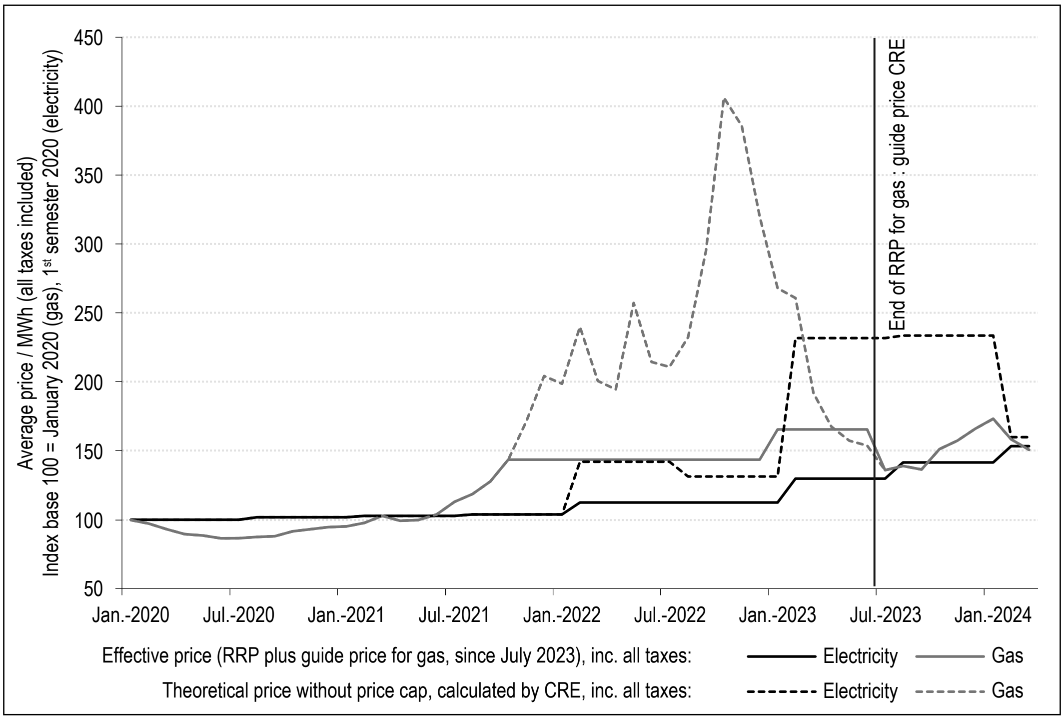
to calculate these prices would normally have integrated these fluctuations, leading consumer prices for gas to rise to levels which might have become prohibitively high for households. This marked the point at which the government began to intervene to steady gas prices. The first price capping measure consisted in freezing the regulated gas price for households at the end of 2021 and for the whole of 2022. For electricity, a similar mechanism was applied to the regulated price in 2022, keeping price increases in 2022 to 4% instead of the estimated 30% which had been forecast. In 2023, the price increase was capped at 15% for both domestic gas bills and electricity. Without this measure, prices would have doubled.

In order to mitigate the impact of this price cut on suppliers' costs, the cap was partly made possible by removing some of the taxes usually paid by electricity consumers (the Interior Tax on End Electricity Consumers; TICFE – and the Local Tax on End Electricity Consumers; TCCFE). Supplementing this measure, the CRE announces a theoretical price – the price which would have been applied where there no price cap – and the government pays the difference directly to the suppliers. To assess the total cost of this policy, we must add up the value of the tax discount and the subsidy as shown in Figure III below, which shows the resulting mean theoretical and applicable prices; in this graph, the difference between the dotted lines and the solid lines represents the cost of the measure (excluding the tax discount, because the prices shown are pre-tax) to the government.

Regulation of gas prices came to an end on 30 June 2023, at the same time that the price cap scheme for gas was wound down. Since that date, the CRE has published a "guide price" calculated in much the same way as the old, regulated retail price (hereafter "RRP"), although suppliers are free to set their own retail prices. In Figure III, and elsewhere in this study, we use this guide price as the price indicator for June 2023 onwards (see Figure A3-II in Appendix 3).

As for electricity, in light of falling gas prices the government decided that the price cap would come to an end in 2025, and from 2024 onwards the TICFE would be gradually increased from the 0.0001 euro/kWh rate in place since the capping policy was introduced (in late 2021 it was around 0.03 euro/kWh). In 2024, the regulated retail price for electricity (RRPe) published by the CRE once again became the benchmark price, i.e. it was considered sufficient to pay energy suppliers without any further compensatory remuneration from the government; this measure has been wholly funded by an initial tax increase (see Figure A3-I).

Figure III – **CRE regulated retail prices for gas and electricity**



Note: The dotted lines correspond to the annual averages.
Source: Energy regulation commission, authors' calculations.

In practice, the aim of this measure is to cap the unit price of a kilowatt-hour of energy, including all taxes. In theory, there are no conditions pertaining to the quantity of energy consumed. However, in the meantime the government also launched a campaign encouraging consumers to reduce their energy consumption, raising the spectre of electricity shortages if demand were to outstrip supply capacities. In 2022, electricity and gas consumption did fall in spite of what was a relatively small increase in prices. Nonetheless, it is difficult to determine whether this was a direct consequence of campaigns encouraging more responsible energy consumption, or else a trend motivated by fears of further price rises.

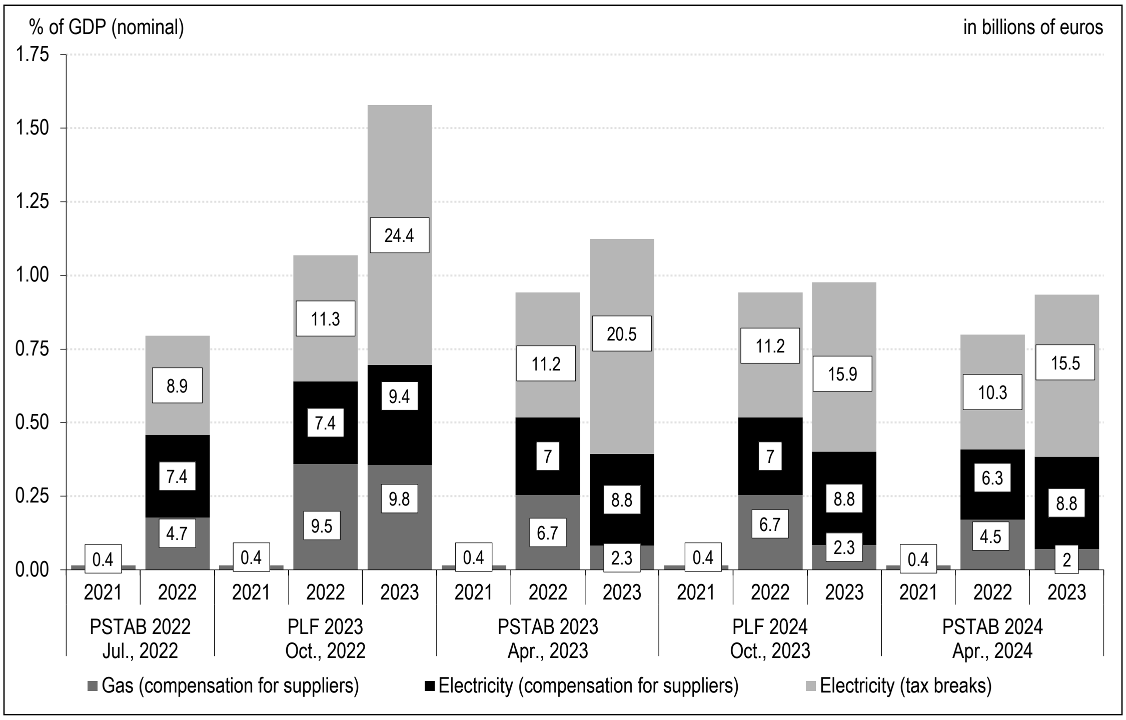
The most recent figures published by the French government in the Stability Programme (PSTAB) for 2024 (published in April 2024) estimate that this measure alone cost 4.5 billion euros for gas and 16.6 billion for electricity in 2022. In 2023, with wholesale prices falling sharply (by May 2023 they were back below their 2021 average), the cost of the policy was estimated at 24.3 billion euros for electricity and 2 billion euros for gas (see Figure IV). It should be noted that the high estimated cost of the electricity price cap is primarily a result of the design of the pricing system, which incorporates a certain latency into the RRP-setting mechanism.

As mentioned above and demonstrated in Figure III, regulated electricity prices are calculated annually by the CRE, with minor adjustments in the second half of the year. The majority of the theoretical price increase (which determines the cost of this measure) can probably be attributed to the remuneration paid to suppliers, including compensation for losses sustained in the previous year due to the unforeseen increase in market prices. A subsequent update from the CRE explained that the theoretical price of gas was capped at the level dictated by the energy price policy, while in fact it could have been lower on account of the current state of gas wholesale prices.

Furthermore, it is worth noting that the government's own estimates of the cost of these measures have changed significantly from one budgetary exercise to the next (Figure IV), testament to the complexity of budget forecasting in an uncertain context defined by an unprecedented crisis.

Efforts to keep consumer prices down also included a number of targeted measures such as direct subsidies for low-income households ("energy cheques"), measures which cost relatively little compared with the price cap policy. In this article, we omit to consider the increase seen in fuel prices, although it should be borne in mind that a temporary reduction in fuel prices, subsidised by the government, was also introduced in 2022 and benefited all consumers, regardless of the quantities they

Figure IV – **Estimating the cost of the price cap policy in successive annual budgets**



Source: The French Treasury.

consumed. According to the government estimates published in the Stability Programme for 2024, measures taken to mitigate inflation are believed to have cost 39.5 billion euros in 2022 and 33.9 billion euros in 2023, with the price caps on gas and electricity accounting for 54% and 78% of those costs respectively.

2. Modelling Framework and Scenarios

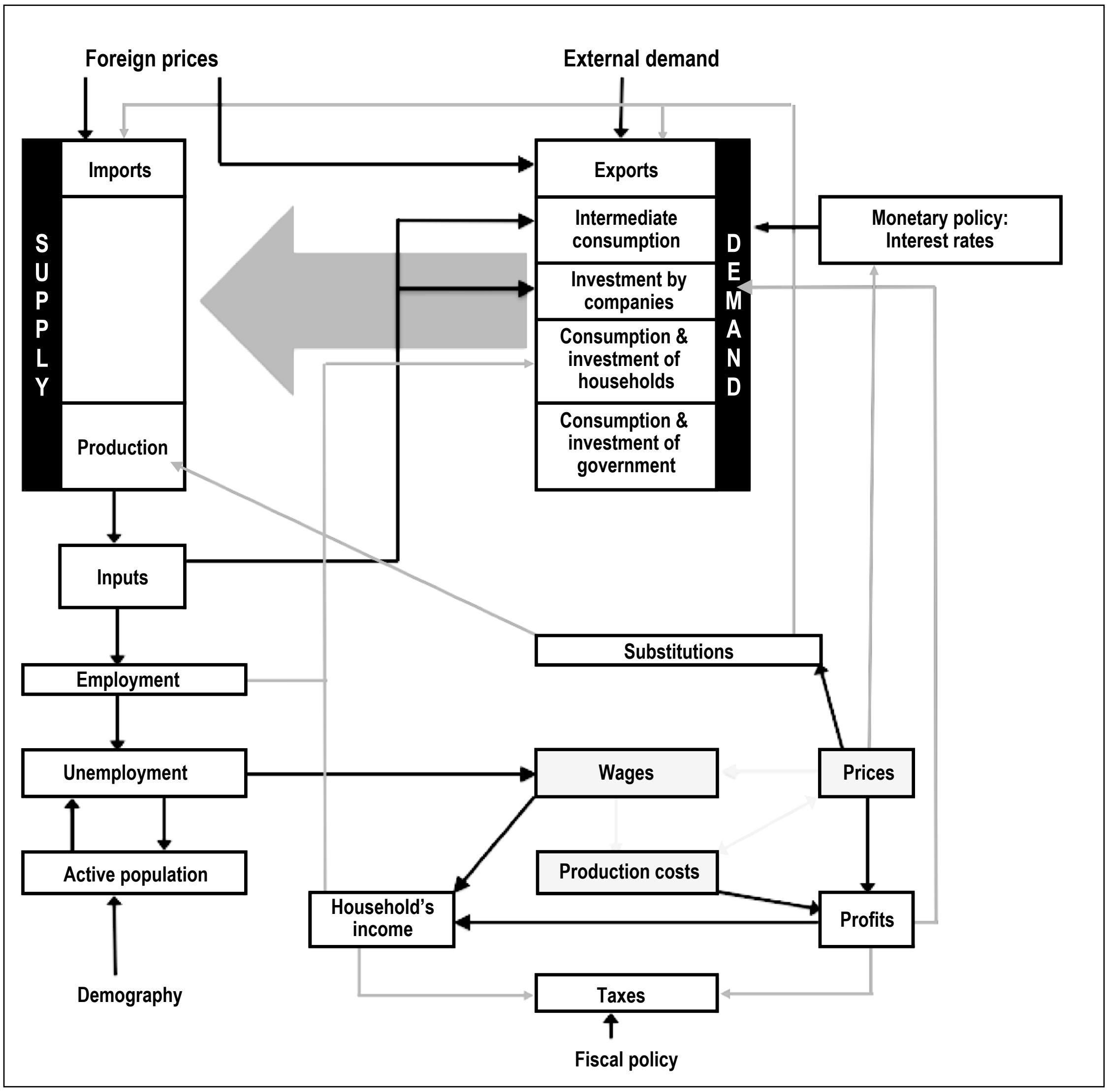
2.1. The ThreeME Model

ThreeME is a computable general equilibrium (CGE) small open economy model, originally developed to help decision-makers design and evaluate measures for decarbonising the French economy (Callonnec *et al.*, 2013; Hamdi-Cherif *et al.*, 2022; Callonnec & Cancé, 2022). ThreeME is specifically designed to evaluate the short, medium and long-term impacts of energy and environment policies at the sectoral and macroeconomic levels. To this end, the model combines several key characteristics:

- Its sectoral disaggregation allows us to analyse activity transfers from one sector to another, particularly in terms of employment, investment, energy consumption and trade balance;
- Its very detailed representation of energy flows within the economy enables us to analyse the consumption behaviour of economic agents regarding energy;
- Sectors may choose between capital and energy when relative energy prices rise, turning to substitute energy vectors;
- Consumers may make substitution decisions between energy vectors, modes of transport or consumer goods.

As a CGE model, ThreeME takes account of feedback effects between supply and demand

Figure V – **Schematic representation of the ThreeME model**



Source: https://www.threeme.org/documentation

(Figure V), as demand (consumption and investment) informs supply (production). Symmetrically, supply can stoke demand by means of the income generated by factors of production (labour, capital, energy products and materials). Compared with *bottom-up* energy models such as MARKAL (Fishbone & Abilock, 1981) or TIMES (Loulou *et al.,* 2005), ThreeME goes beyond simply describing the sectoral and technological dimensions of energy, instead integrating them into a comprehensive macroeconomic model.

ThreeME is a neo-Keynesian model, whereas existing CGE models in the Walras tradition largely concern themselves with supply, and prices are not adjusted instantaneously to achieve market equilibrium. This model is dynamic, and prices and quantities evolve slowly as producers adjust their supply to meet demand. One benefit of this is that it allows for short and medium-term periods of disequilibrium in the market (particularly periods of involuntary unemployment), creating a framework which is particularly conducive to the analysis of economic and energy policies.

This maximises the utility of each agent in period t subject to various constraints, such as market equilibrium (e.g. demand being equal to supply). This is a recursive-dynamic (i.e. short-sighted) model, which means that it begins by optimising the period t and then uses the endogenous results (for example, prices, wages and production levels) to optimise the ensuing period (i.e. $t+1$). Once the model has optimised the final period (as determined by the user), it generates forecasts for endogenous parameters such as prices, household income, GDP and the employment rate, for the whole time frame. ThreeME also requires a number of exogenous parameters: the *Social Accounting Matrix* (SAM) for the reference year, along with forecasts for population growth, the productivity of factors, and various substitution elasticities. SAM is a comprehensive database for the national economy, recording all transactions between economic agents at a given date (Kehoe, 1996). Forecasts for population and economic growth determine the availability of manpower, and shape productivity trends. Elasticities determine the degree of substitution between factors of production within functions of production. With a *Constant Elasticity of Substitution* (CES) function, substitution between factors of production may follow either a linear production function, a fixed proportions (or Leontief) production function, or else a Cobb-Douglas production function. A linear production function represents a production process in which the factors of production are perfect substitutes (for example, labour can be completely replaced by capital). A fixed proportions production function represents a production process in which the factors of production are needed in fixed proportions. In the Cobb-Douglas production function, inputs may be substituted, even if they are not perfect substitutes. ThreeME uses a nested CES production function (Reynès, 2019) to describe the substitution between factors of production. This CES production function, known as KLEM, combines four factors of production: capital (K), labour (L), energy (E) and materials (M). Factors of production may be substituted for one another, with elasticity of substitution parameters determining the degree of substitution between them. Each pairing (i.e. $K-E$, $KE-L$, $KEL-M$) has its own substitution elasticity, explained in greater detail in the description of the model (Reynès *et al.,* 2021). One essential characteristic of standard, Neo-Keynesian AS-AD (aggregated supply and demand) macroeconomic models is that demand determines supply. Demand includes consumption (intermediate and final), investment and exports, while supply comes from imports and domestic production. By means of various feedback mechanisms, potentially involving some delay, supply shapes demand. The level of production determines the quantity of inputs used by businesses, and thus the quantity of their intermediate consumption and investment, two major components of demand. It also determines the level of employment and, as a result, influences final household consumption. Another effect of employment on demand is its influence on wages, by means of the unemployment rate which also depends upon the size of the active population. The size of the active population is primarily determined by exogenous factors such as demographic trends, but it is also shaped by endogenous factors such as the labour market participation rate.

2.2. Calibrating the ThreeME Model and Integrating CRE Data

For the French context, the ThreeME model was calibrated using data from the national accounts, available from Eurostat. Our reference year was 2015. After that reference year, the only shock we took into consideration was the global increase in energy prices beginning in 2021, in order to represent and isolate the trends observed in energy prices and analyse them independently of any other economic fluctuations. This shock was accounted for by integrating the increase in the Dutch TTF with a transmission coefficient of 50%. In order to model consumer prices of energy in France, we made a further adjustment to the consumer price setting mechanisms in order to accurately reflect the price regulation structures described above. All of the other equations retain the standard specifications of the ThreeME model as usually applied in France.

2.2.1. Energy Prices

Within the framework of this model, the price equations rely on adjustment processes (see Appendix 2). For the purposes of this article, we modified the household price equations for two energy products: electricity and gas. In order to integrate the effects of the energy price cap policy, the two pricing equations for both energy products are determined exogenously so as to reflect the administered nature of these prices, in both the reference scenario and the scenario integrating the price cap as the price observed during the preceding period, to which we apply the price increase ratio fixed by the government (in both scenarios).

In formal terms, this can be written as follows:

$$P^{CH}_{ce,t} = \left(1 + \tau_{ce,t}\right) P^{CH}_{ce,t-1} \qquad (1)$$

where $P^{CH}_{ce,t}$ is the consumer price index for the period t for the energy products ce, gas and electricity, and $\tau_{t,ce}$ the annual growth rate calculated exogenously. For other consumer goods, we used the default pricing mechanism associated with this model, which submits prices to a process of adjustment. In order to model the impact of government policy, we include a reference price which corresponds to the CRE's theoretical price, alongside the regulated price. The difference between these two prices represents the cost of the policy to the government. In our reference scenario the two prices are equal, so the cost of the policy is essentially zero. Unlike the real policy framework surrounding the price cap, whose tools are broader in their scope, our simulations do not include that part of the policy financed by the tax exemptions mentioned in Section 2.2, simply because the taxes in question do not have a return effect for consumers within the standard ThreeME model. This means that the results of our simulations concerning the cost of the policy cannot be directly compared with the observed budgetary cost.

In order to obtain the energy price series used to calibrate our scenario, we calculated average consumer prices using the RRP. For electricity, the CRE publishes RRPe figures applicable under the price cap scheme (with and without taxes), as well as theoretical RRP figures without taxes. The theoretical RRP including tax was thus recalculated, based on the assumption that without the price cap the TIFCE tax would have remained at its late-2021 level. On the basis of these two data series, we used the standard consumer profile defined by the CRE, signed up to the "blue" basic price scheme with an annual energy consumption of 2,400 kWh, at a power of 6 kVA. This enabled us to estimate an average price-per-kWh, taking fixed costs into account.

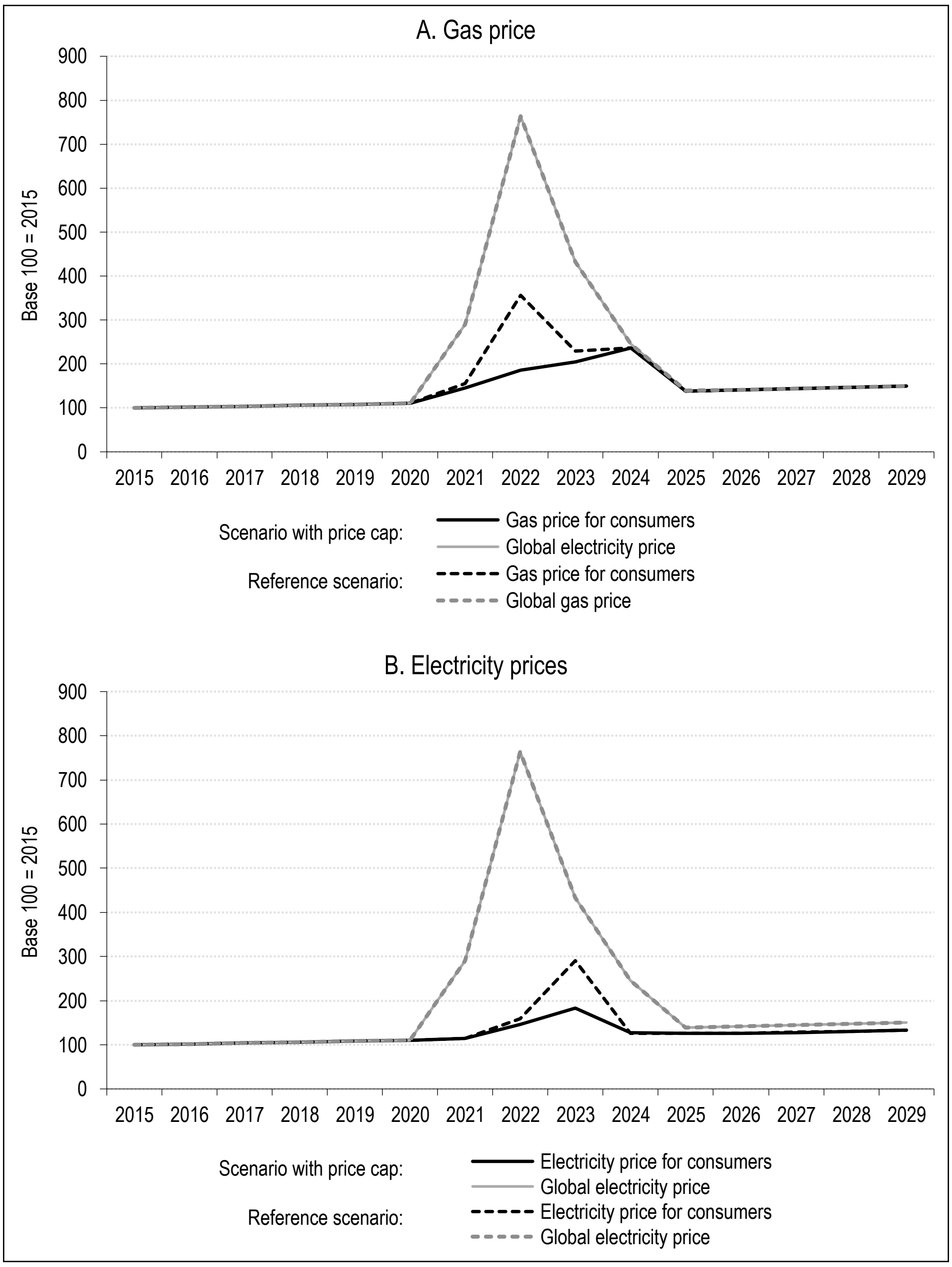
A similar approach was adopted for gas, where the CRE standard customer used for the purposes of our study is a consumer using gas for hot water, cooking and heating, with an annual consumption of 13.48 MWh at local price level NP2.

The trend evolution of energy product prices, as modified in ThreeME for the purposes of this study, is presented in Figure VI hereunder. With the exception of the period 2021-2024, the trend for all prices was a year-on-year increase of +2%. For wholesale prices, based on empirical observations of the Dutch TTF, we recorded a price shock consisting of a 162% increase in 2021, repeated in 2022. We then reduced prices by 43% in 2023 and 2024. The shock applied until 2021 (inclusive) differs from the empirical fluctuations of the Dutch TTF, because the annual average price of gas hit a historic low in 2020, before increasing by 400% in 2021 and 177% in 2022. For the ThreeME simulations, we decided to smooth the variation in gas prices between the reference year (2015) and 2022 in order to obtain a stable trend for the years leading up to 2022, so as to facilitate both the calculations and the analysis of the results.

The reference scenario used for comparison corresponds to a world where no effort is made to keep consumer prices down. As such, we took the theoretical average increase in prices (before tax) determined by the CRE as our point of reference. For the purposes of our analysis, we then modified this consumer price specification to include the pre-tax price fixed under the price cap scheme.

We made one final modification to the model to ensure that energy consumption responded quantitatively to changes in prices, as seen in 2022 (corrected for meteorological effects), with electricity and gas consumption falling by 1.7% and 6.2% respectively. We also calibrated the proportion of household energy demand which can be regarded as autonomous consumption in order to replicate the imputed decline in consumption for the years 2022 and 2023.

Figure VI – **Example of energy prices calibration in the ThreeME model**



Source: ThreeME simulations.

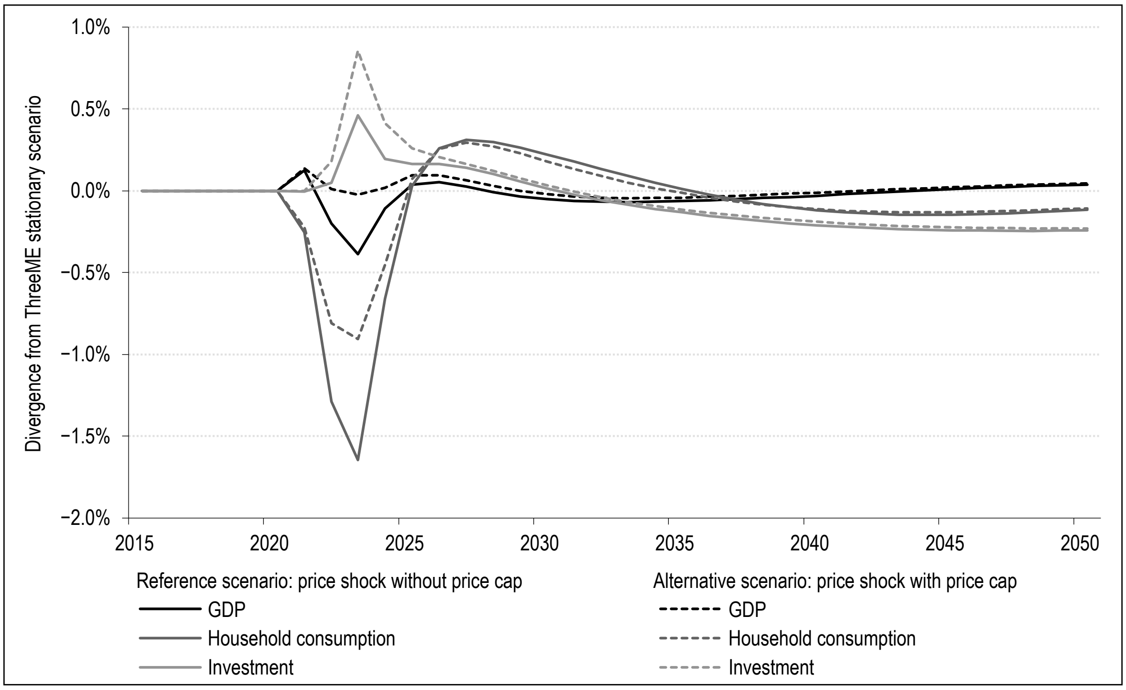
3. Results

We ran simulations using the ThreeME model for a period of 35 years, starting from our reference year 2015 (the year for which the model was calibrated using Eurostat data) and modelling the two scenarios described above.

Throughout the rest of our analysis we compare the results of the price cap policy with a reference scenario, which is essentially a variant where a shock affecting global energy prices upsets the steady state ThreeME model, along with an exogenously-determined variation in the consumer prices paid by households, reflecting the energy pricing policy adopted in France. The steady state scenario, meanwhile, is constructed with a steady growth rate of 1.25% and stable inflation of 2%. Figure VII presents a comparative plot of the price shock scenarios and the steady state scenario, giving a clearer picture of the impact of the crisis which is modelled hereunder. This graph shows that, at its peak in 2023, the price shock caused GDP to fall by around 0.4%, primarily because household consumption fell by more than 1.6%. We also observed an increase in investments, in spite of the slowdown in activity which was expected during the crisis. This can be attributed to substitution between energy and capital as factors of production, in response to rising energy prices. The GDP increase seen in 2021 can be attributed to falling gas imports, with the effect of the electricity price shock not felt until 2022.

The third scenario, the "price cap scenario," incorporates the price capping measures imposed on gas and electricity sales to private consumers. It is important to bear in mind that our calculations do not include any other price shocks, such as the spike in inflation observed from the second half of 2022 onwards, nor did we seek to model the economic impact of COVID-19. Our goal was to isolate the energy price shock and the political response. As a result, the majority of the results of this simulation are best understood in terms of the relative difference between the alternative scenario and the reference scenario.

Figure VII – **Price shock scenarios, compared with ThreeME stationary scenario**



Note: The variables are given in volume terms.
Source: ThreeME simulations.

We can see that incorporating the price cap increases real GDP by 0.2% in 2022 and 0.4% in 2023, as demonstrated in Figure VIII. This increase can be primarily attributed to household consumption, which is 0.8% greater in 2022 than it would have been had no measures been taken to mitigate energy price inflation. This indicates that the policy has indeed protected consumers' purchasing power, as illustrated by the difference in energy consumption.

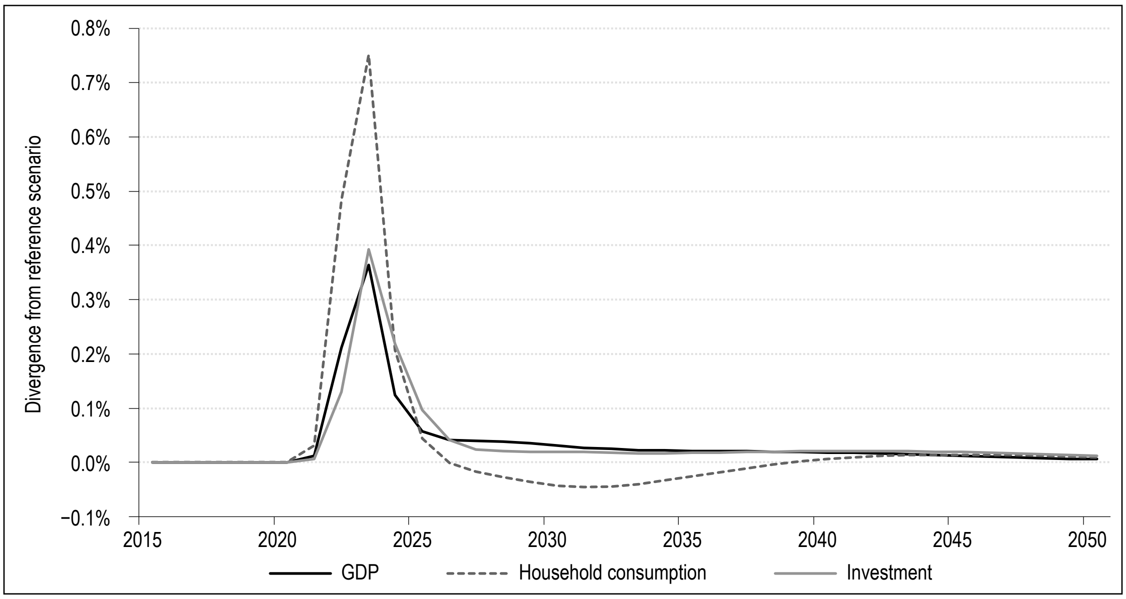
Completing our analysis of these results, Figure VII indicates that the price cap scheme nearly halves the decline in household consumption in 2023, and virtually cancels out the decline in activity caused by the price shock in 2022 and 2023.

Consumption of natural gas falls by 5.2% in 2022, instead of the projected 17.3% (see Figure A1-I in Appendix 1). Similar results are obtained for electricity consumption in 2023, which falls by 5.9% instead of 16.4%.

The balance of trade, already showing a deficit, further deteriorated (Figure IX) because imports grew in response to increased demand from households. Moreover, given that the majority of gas consumed in France is imported, the reduction in consumer prices brought about by the price cap actually led to an increase in demand. As a result, in comparison with the reference scenario, our results show that the trade deficit widened by 0.21 GDP points in 2022 and 0.16 points in 2023.

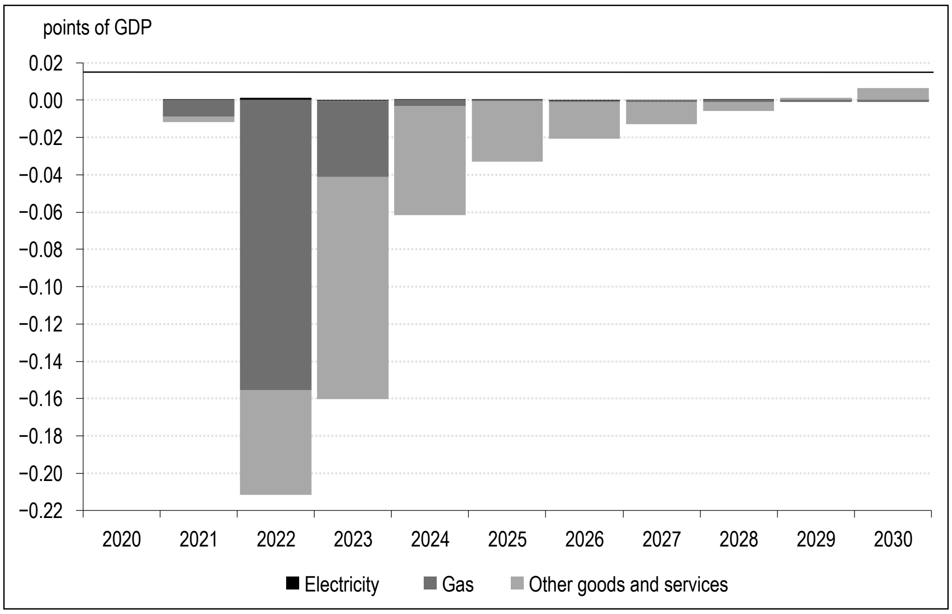
Medium-term variations in imports and exports compared with the reference scenario are detailed in Appendix 1 (see Figure A1-II). They show a peak increase in imports when the price cap is in place, then a post-crisis increase in exports thanks to more favourable terms of

Figure VIII – **Impact of the price cap: GDP and its national components**



Note: The variables are given in volume terms.
Source: ThreeME simulations.

Figure IX – **Balance of foreign trade by product, expressed in percentage points of nominal GDP (absolute divergence from reference scenario)**



trade made possible by domestic price subsidies. Nonetheless, the balance of trade (Figure IX) continues to deteriorate, albeit to a lesser extent, in comparison to the reference scenario. This decline stops in 2030.

3.1. Estimating the Budgetary Cost

With regard to public finances, nominal public spending increases by 0.7% in 2022 and 0.8% in 2023, largely as a result of the cost of this policy. In 2022, these simulations estimate the cost of the policy at approximately 0.6% of nominal GDP, with the cost of the electricity price cap accounting for 15% of the total cost, and the gas price cap accounting for the rest (i.e. 85%, see Figure XI).

In the following year, the cost of the electricity price cap increases significantly. This increase results from the inclusion, in the regulated price, of costs intended to offset the high prices seen on the wholesale gas market, which had not been taken into consideration for the preceding year.

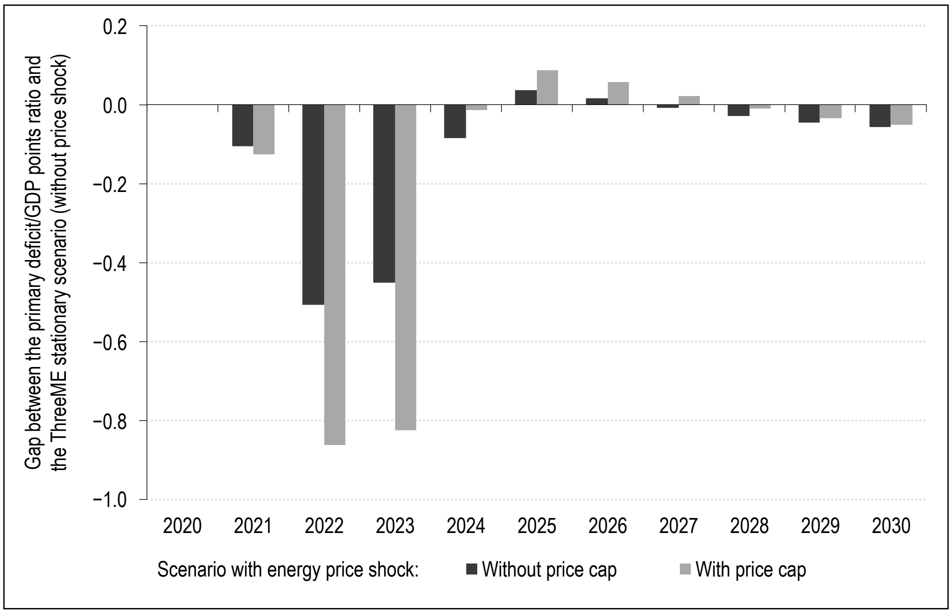
As a result, the total cost of the price cap policy stands at around 0.7% of nominal GDP for the year in question, with electricity accounting for approximately 90% of that cost.

For natural gas, however, falling prices on the wholesale market serve to drive down the cost of the price cap policy. As noted by the CRE, even though the theoretical gas price could be even lower, it is fixed at the regulated price for Q2 2023, which has the effect of offsetting the cost of the policy for the rest of the year. This decrease can also be partly attributed to the end of the gas price cap policy in June 2023, and the end of regulated pricing.

On account of the cost of the price cap policy, the public spending deficit (Figure X) deteriorates further in comparison to the reference scenario, which already incorporates the shock associated with the slowdown of economic activity.

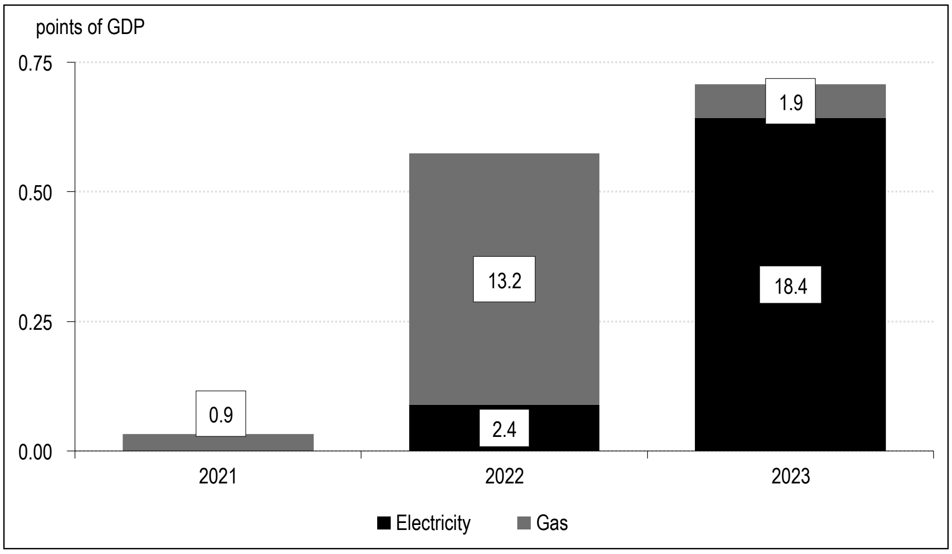
In the context of the model used here, interest rates are regarded as exogenous factors which do not respond to inflation. As such, although inflation has the effect of worsening the deficit

Figure X – **Primary deficit to GDP ratio, for each scenario**



Note: The primary deficit/GDP ratio in the ThreeME stationary scenario is −0.9 point of GDP. As such, even when the difference with the latter is positive, as it is in 2025, the primary balance remains clearly in deficit.
Source: ThreeME simulations.

Figure XI – **Estimating the cost of the energy price cap policy**



Note: The values shown in Euros were computed in the context of the ThreeME simulations and are not directly comparable with the real costs.
Source: ThreeME simulations.

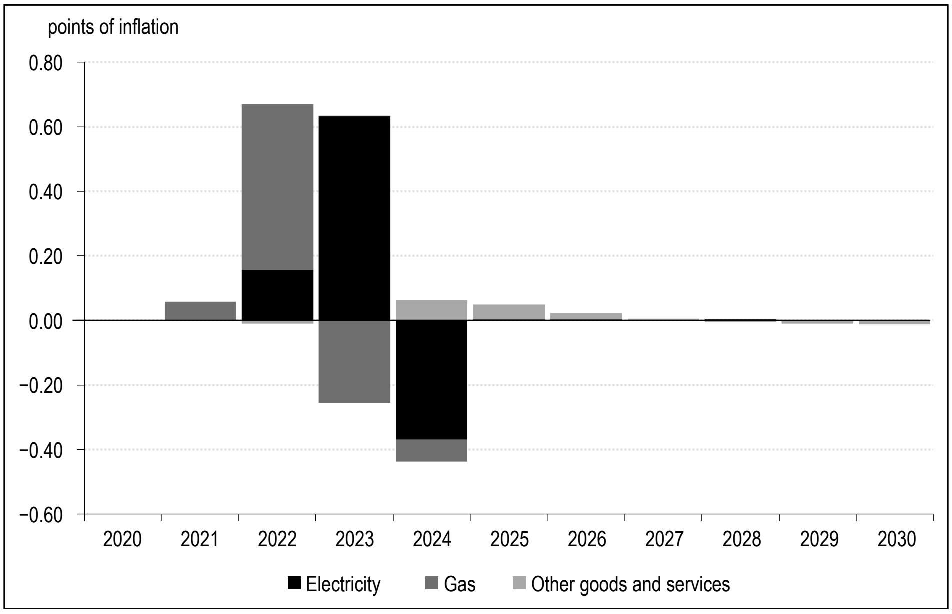
during the crisis, the fall in prices observed post-crisis has a positive impact on the accumulated debt burden when calculating the primary deficit. Nevertheless, this effect is fleeting. Subsequently, we can observe a second, slight but enduring deterioration in the deficit in terms of nominal GDP. This can be attributed to an insufficiently robust economic rebound.

For the period to 2030 the budgetary coefficient remains below one, dipping to 0.6. The reduction in inflation made possible by the price cap measure, combined with the boost to economic activity provided by the decision to shield energy prices, are not sufficient to offset the long-term cost of the policy.

During the period when the price cap was in place, we noted an overall reduction of inflation by 0.6 pp in 2022 and 0.4 pp in 2023 (Figure XII). In 2024, energy prices rose more sharply in our model than in the reference scenario, contributing to an overall 0.4 pp increase in inflation (the contribution of energy products to the inflation differential is 0.4 pp). The price cap also serves to mitigate inflation in the cost of goods and services other than energy, with inflation falling to a lesser extent during the period in question.

Since the purpose of the price cap policy was to protect household purchasing power by mitigating the rise in energy prices, the consequences for emissions are, unsurprisingly, similar to those recorded for energy consumption, namely an increase in direct greenhouse gas emissions from households in comparison with the reference scenario, peaking at 2.5% in 2023 and then falling back to their initial level (see Figure XIII).

Figure XII – **Impact of the price cap on inflation, by contribution (divergence from reference scenario)**

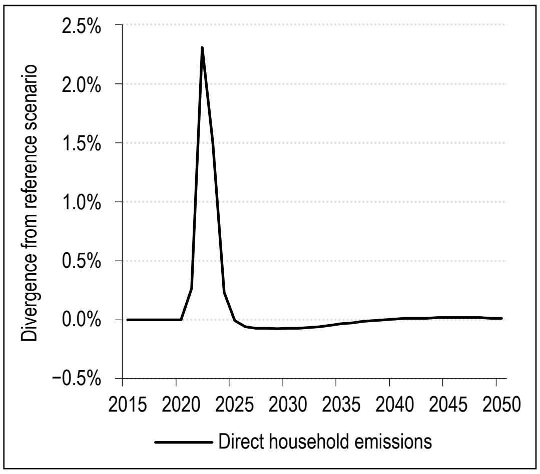


Source: ThreeME simulations.

3.2. Sensitivity Tests

The results of our simulations are immediately dependent upon the distribution of parameters used when calibrating the model, both in terms of sensitivity to price changes (price elasticity) and the speed at which such reactions occur (adjustment parameters). In order to assess the sensitivity of our macroeconomic results to the choices made regarding these parameters, we

Figure XIII – **Direct household emissions (divergence from reference scenario)**



Source: ThreeME simulations.

simulated multiple variants of the same price cap scenario, each with a different value for substitution elasticity η^{LESCES} in the equation for marginal propensity to consume (Equation 24 in Appendix 2). In our central scenario, the price-elasticity value is equal to −0.5, and in this section we test six alternative values {−1; −0.8; −0.6; −0.4; −0.2; 0}.

We thus see that the effect of the price cap policy on consumption sits somewhere between 0.39% (elasticity at −1) and 0.64% (elasticity at 0) for 2022, and between 0.57% and 1.03% for 2023, converging very rapidly around the central value for the effects actually observed once the policy was rescinded (Figure XIV). The effect measured in terms of GDP variation remains similar, ranging from 0.48% (price elasticity at −1) and 0.28% (price elasticity at 0). These tests tell us that although the amplitude of the effect observed is heavily dependent on the choice of value utilised for this parameter, the macroeconomic dynamics we identified remain valid nonetheless.

4. Discussion

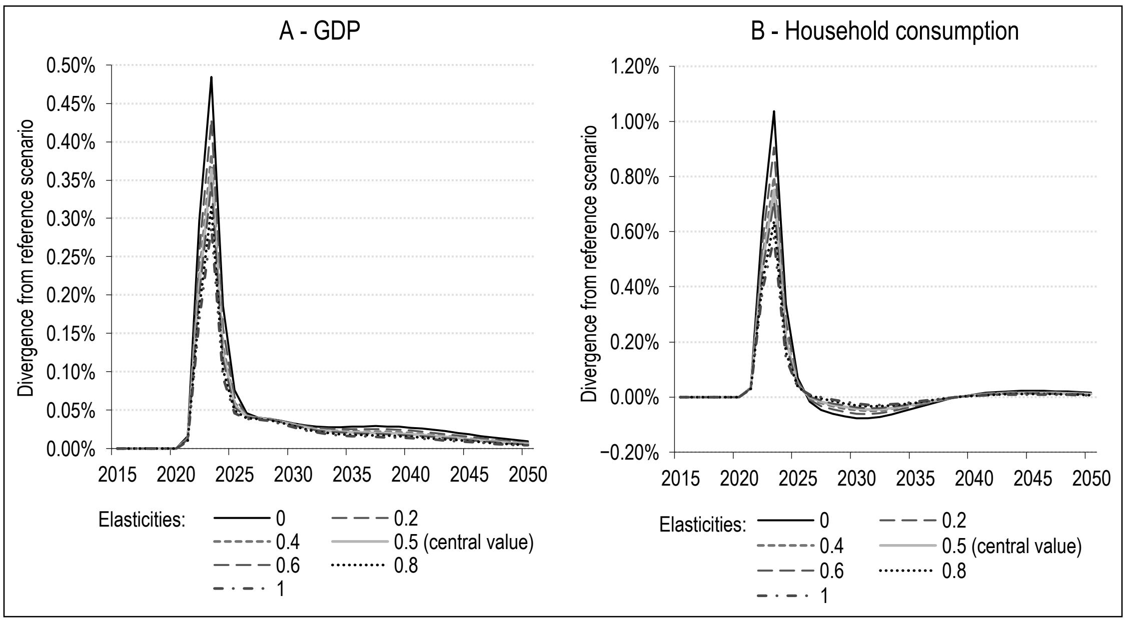
The price cap policy was remarkably efficient at achieving its initial objectives, particularly protecting consumer purchasing power and keeping the high rate of inflation under control. In 2022 and 2023, a significant reduction in energy consumption was observed, which can be ascribed not only to rising prices and favourable meteorological conditions, but also to the context of uncertainty surrounding future price developments.

Regarding inflation, the National Institute of Statistics and Economic Studies (INSEE) estimates that this policy succeeded in cutting France's rate of inflation in half (Bourgeois & Lafrogne-Joussier, 2022).

In terms of all-round efficacy, policies of this nature raise several questions, with regard to both their long-term economic implications and their structural consequences. One of the great disadvantages with public policies of this kind is that they neutralise price signals, and thus do not necessarily encourage households to restrict their consumption as much as they would have done in the absence of such measures. By way of a comparison, the German system more effectively integrates the price signal dimension by protecting only a certain proportion of consumption, with the rest remaining subject to market prices.

France opted to implement a policy which was beneficial to all consumers, as when the government took measures to reduce fuel prices, with no means-testing of these benefits. As noted in our results, household consumption was higher when the price cap was in place. Making this a means-tested measure would avoid the risk of subsidising the consumption of households who are relatively impervious to fluctuations in energy prices, while helping low-income households to escape energy poverty, in line with

Figure XIV – **Impact on household consumption and GDP, applying multiple price elasticity values to the household demand function**



Source: ThreeME simulations.

the conclusions reached by Chaton & Gouraud (2020). In order to simulate such specifications in ThreeME, we would have needed to adjust the model so as to split households into categories based on their level of income. This is not possible with the version of the model we used. Similar, or even better, results would most likely have been obtained if household resources could have been taken into consideration as a condition.

We have already noted that the cost of the policy depended not only upon the pricing system, but also, as expected, on gas prices on the wholesale market. These prices are highly volatile (as demonstrated by Figure III), which means that predictions for the final cost of the policy are highly uncertain and dependent upon the current price at time of calculation. The French Finance Ministry has issued a series of forecasts at approximately six months intervals as part of their annual budget calculations, starting with the annual budget forecast for 2023, published in 2022. The most recent available figures come from the 2024 Stability Programme, published in April 2024. The decline in gas spot prices observed since late August 2022 has drastically reduced the overall cost of the price cap policy, when compared with the government's initial estimates. For the year 2023, for example, the initial estimate for the cost of the gas price cap was 9.8 billion euros; this was when Dutch TTF prices were at their peak. This estimate was revised to just 2 billion euros in April 2024, following a significant fall in prices (cf. Figure IV). The Dutch TTF returned to levels comparable to those last seen before the energy crisis.

While this may not appear to be a problem *per se* – in principle, less costly policies are always welcome, especially coming after several years of unscheduled spending increases – it is nonetheless difficult to ignore, particularly in these uncertain times, the possibility that things could go the other way, i.e. that energy prices could remain high for an extended period of time, thus exacerbating the burden placed on public finances.

This raises questions as to how political decision-makers handle unscheduled expenditure, with potential consequences including a blow to the credibility of their economic policies, as well as unexpected increases in government debt. We might also suggest that overestimating the budgetary cost of policies could have a crowding out effect on the public finances, ultimately influencing the allocation of funds between different policies within the budget, and undermining the efficiency of this allocation.

The primary aim of the research presented here is to evaluate a policy which involved capping prices during a time of crisis. Nonetheless, this evaluation runs up against certain limitations arising from the modelling framework used. It is important to bear these limitations in mind.

When evaluating the cost of the price cap policy, we note that our results differ from the government's own estimates (see Figure IV), even when we remove the effective cost of the fiscal exemptions, which were not taken into account by ThreeME. This suggests that the government estimates might be based on different estimates for theoretical energy prices. In the most recent government estimates (PSTAB 2024), the "compensation to suppliers" paid under the gas price cap scheme is estimated at 4.5 billion euros in 2022 and 2 billion in 2023 (compared with 13.2 billion and 1.9 billion in our simulations). For the electricity price cap, the government estimates are 10.3 billion euros for 2022 and 15.5 for 2023 (compared with 2.4 billion and 184 billion in our simulations). It thus appears that our simulations overestimate the cost of the gas price cap in 2022, and yield a different picture for the distribution over time of the cost of the electricity price cap.

Nonetheless, the sum totals for these two years remain comparable, albeit slightly overestimated: for 2022 they stand at 14.8 billion euros (PSTAB 2024) compared with our 15.6 billion (ThreeME), and for 2023 the figures are 17.5 billion euros (PSTAB 2024) to our 20.3 billion (ThreeME). Our study does not include one component of the price cap scheme, namely the partial tax exemptions on gas and electricity which also helped to drive prices down. We should also note that, although the model appears to behave in a largely linear manner, it is not necessarily possible in this specific case to estimate by extrapolation the effect of the price cap policy as a whole, i.e. including the tax exemptions not taken into consideration by this study. These tax breaks applied only to the electricity price cap, while our simulations offer combined results for both gas and electricity.

Another limitation of this study is the way it models foreign trade. Our model is constructed to study France, and although the French economy is open this is only represented by a "rest of world" component, with little responsiveness apart from global demand which responds to fluctuations in relative prices. Within the context of this analytical exercise, the rest of the world is not affected by the energy price shock: the analytical framework therefore does not accurately represent all of the shocks engendered by the sudden spike in energy prices in Europe. One of the direct consequences of this increase might be a decrease in the demand for French goods from France's trading partners, first and foremost fellow EU members, which would theoretically exacerbate the trade deficit by accelerating the decline in exports. The political responses of other countries to the price shock are also overlooked, despite the fact that France's principal European partners also introduced measures to attenuate price increases and protect their economies, measures which had knock-on effects for energy prices, as demonstrated by Bayer *et al.* (2023). For these reasons, the results for foreign trade could be less positive for the French economy.

* *
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Our simulations show that the price cap system succeeded in protecting economic activity: compared to a reference scenario without price capping, GDP was 0.2% higher in 2022 and 0.4% in 2023, at a budgetary cost estimated at 0.5% of nominal GDP in 2022 and 0.7% in 2023. We estimate the budgetary coefficient for the eight years following the introduction of this policy at 0.6. Moreover, household consumption in 2022 was 0.75% higher than it would have been without the measure.

It is, however, important to bear in mind the emergency context in which these policies were introduced and the speed with which they were rolled out, largely by replicating an existing instrument which had previously been implemented in overseas regions and *départements*.

As such, although the price cap scheme succeeded in keeping inflation at manageable levels, particularly for those households most exposed to it, it is nonetheless difficult to regard it as a viable long-term policy, as it pays too little heed to the efficacy of public spending, and seems at odds with policies aimed at speeding the transition to a low-carbon economy. Introducing an indirect subsidy for final energy consumption has the effect of scrambling the price signal, a signal which could have encouraged greater moderation in energy consumption.

This research makes use of a modelling approach (the ThreeME model) capable of representing the sectoral specificities of a targeted price shock. Our work could be expanded to fully integrate the other components of the price cap policy – such as direct transfers to households or tax exemptions on energy products – in order to more precisely calculate their budgetary cost. Evaluating public policy with the help of a model which combines a climate and energy component with a multisectoral, macroeconomic analytical framework also highlights how important it is for institutions to better integrate these considerations into the traditional mechanisms of policy-making, even when the policies in question are designed to respond to short-term challenges. ☐

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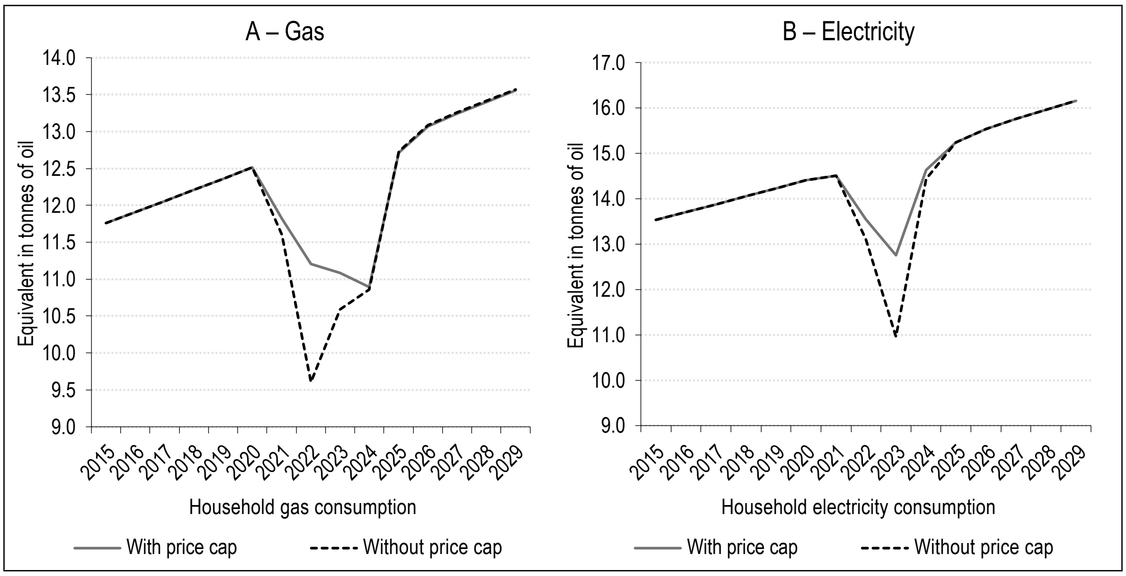
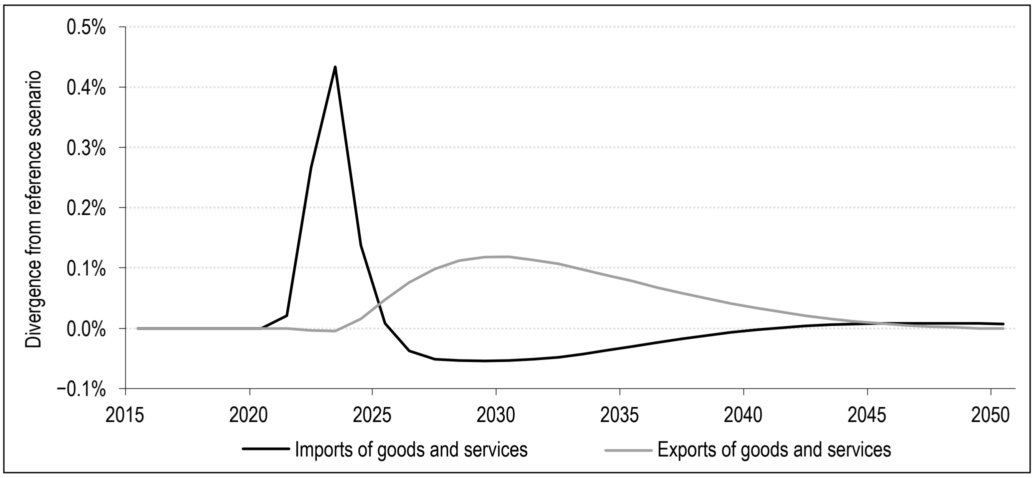
RESULTS

Figure A1-I – **Household energy consumption**



Source: ThreeME simulations.

Figure A1-II – **Impact of the price cap on foreign trade (divergence from reference scenario)**



Source: ThreeME simulations.

APPENDIX 2

THE PRINCIPAL EQUATIONS USED BY ThreeME

Specifications of the Adjustment Mechanisms

Unlike Walras-inspired models which presuppose that supply and demand are always perfectly balanced, with perfect flexibility of both prices and quantities, ThreeME takes a more realistic view of the way in which the economy functions, explicitly incorporating the gradual adjustment of prices and quantities (factors of production, consumption). Within this Keynesian framework, permanent or transitory balances of under-employment are possible, with demand shaping supply. ThreeME supposes that real levels of prices and quantities gradually adjust to their notional levels. The notional level corresponds to the optimal level (desired, or targeted) that the economic agent in question (businesses for prices and demand for factors of production, households for consumption, the central bank for interest rates, etc.) would choose if adjustment constraints were not an issue. These constraints primarily arise from adjustment costs, physical or temporal limitations and other sources of uncertainty. In formal terms, we assume that the adjustment process and forward planning regarding prices and quantities can be represented by the following equations:

$$\log X_t = \lambda_0^X \log X_t^n + \left(1-\lambda_{0,t}^X\right)\left(\log X_{t-1} + \Delta\left(\log X_t^e\right)\right) \quad (2)$$

and

$$\Delta\left(\log X_t^e\right) = \lambda_t^{1,X}\,\Delta\left(\log X_{t-1}^e\right) + \lambda_t^{2,F}\,\Delta\left(\log X_{t-1}\right) + \lambda_t^{3,X}\,\Delta\left(\log X_t^n\right). \quad (3)$$

Where X_t is the real value of a given variable (for example, production price, labour, capital etc.), X_t^n represents its notional level, X_t^e is its expected value for the period t, and α_i^X are the adjustment parameters (and $\alpha^{1,X} + \alpha^{2,X} + \alpha^{3,X} = 1$).

Equation (2) supposes a geometric process of adjustment. Taking expectations into account ensures that the real variables converge towards their desired long-term levels. Equation (3) supposes that these expectations are adaptable (retrospectively). It is worth noting that equation (2) and equation (3) can be reformulated within an error correction model, as used to produce econometric estimates, in order to account for the non-stationary nature of certain variables:

$$\Delta\log\left(X_{t-1}\right) = \alpha_1\,\Delta\log\left(X_{t-1}\right) + \alpha_2\,\Delta\log\left(X_{t-1}^n\right) - \alpha_3\log\left(X_{t-1}\right)/\left(X_{t-1}^n\right).$$

To do so, the following constraints must be respected:

$\lambda_0^X = \alpha_3, \lambda_1^X = 0, \lambda_2^X = \alpha_1/\left(1-\alpha_3\right), \lambda_3^X = \left(\alpha_2-\alpha_3\right)/\left(1-\alpha_3\right).$

We also suppose that the substitution effects $\left(SUBST_X\right)$ adjust slowly to the notional substitution effects$\left(SUBST_X^n\right)$:

$$SUBST\_X_t = \lambda_4^X\ SUBST\_X_t^n + \left(1-\lambda_4^X\right)*SUBST\_X_{t-1}. \quad (4)$$

The three equations shown above allow for a broad array of adjustments, as they integrate different forms of rigidity (on prices and quantities, on expectations and on substitution mechanisms). By way of an example, let us consider the full specification for demand for labour (L). For simplicity's sake, the sectoral index is omitted. Notional demand for labour (L^n) can be derived by minimising production costs. It is positively dependent upon production levels $\left(Y\right)$, negatively dependent upon the productivity of labour ($PROG_L$) and another component combining all of the substitution phenomena with the other factors of production ($SUBST_L$):

$$\Delta\log\left(L_t^n\right) = \Delta\log\left(Y_{t-1}\right)\Delta\log\left(PROG\_L_t\right) + \Delta SUBST\_L_t. \quad (5)$$

We introduce a distinction between the real and notional substitution effects, in order to take account of the fact that demand for labour generally responds more rapidly to changes in the level of production than to substitution phenomena: while it is physically necessary to use more labour to respond to an increase in production, substitutions imply making changes to the structure of production, and implementing these changes may take longer. Real substitution thus adjusts gradually to notional substitution $\left(SUBST_L^n\right)$, which depends on the relative prices of the factors of production:

$$\Delta SUBST\_L_t^n = -\eta^{LK}\varphi_{t-1}^K\Delta\log\left(C_t^L/C_t^K\right) - \eta^{LE}\varphi_{(t-1)}^E\Delta\log\left(C_t^L/C_t^E\right) - \eta^L\varphi_{t-1}^M\Delta\log\left(C_t^L/C_t^M\right) \quad (6)$$

where η^{LK}, η^{LE}, η^{LM} are the substitution elasticities between labour and the other factors of production, capital, energy and materials (i.e. intermediate consumption not related to energy) respectively. φ^K, φ^E, φ^M represent capital, energy and materials, respectively, proportionally to total production costs. C^K, C^L, C^E, C^M are the unit production costs of capital, labour energy and materials, respectively. In the following section, we provide more details regarding the derivation of demand for these factors. Finally, as the adjustment mechanisms are defined by means of equations (4), (5) and (6), the three following ratios are used:

$$\log\left(L_t\right) = \lambda_0^L\log\left(L_t^n\right) + \left(1-\lambda_0^L\right)\left(\log\left(L_{t-1}\right) + \Delta\log\left(L_t^e\right)\right)$$

$$\Delta\log\left(L_t^e\right) = \lambda_1^L\,\Delta\log\left(L_{t-1}^e\right) + \lambda_2^L\,\Delta\log L_{t-1}) + \lambda_3^L\,\Delta\log\left(L_t^n\right) \quad (7)$$

$$SUBST_{L_t} = \lambda_4^L\ SUBST_{L_t^n} + \left(1-\lambda_4^L\right)SUBST_{L_{t-1}}. \quad (8)$$

Production Functions and Demand for Factors of Production

The structure of production is broken down into three levels (see Figure A2). The first supposes a function of production operating with four inputs (or factors of production), often denoted by the acronym KLEM (capital, labour, energy and materials). The first level also incorporates a fifth element: transport and commercial margins. Strictly speaking, the latter should not be considered as factors of production, since they come into play after the production process. As such, they cannot be substituted for the factors of production. Nevertheless, they are inextricably linked with production levels, since once goods have been manufactured they need to be transported and brought to market. At the second level, aggregates for investment, energy, materials and margins are broken down with reference to the type of products involved (e.g. energy sources). At the third level, demand for each factor or margin is either imported or produced locally. Demand for factors of production is derived by minimising companies' production costs. We assume that the function of production has constant returns to scale, more general than CES (constant elasticity of substitution), to the extent that substitution elasticities may vary from one pair of inputs to the next (Reynès, 2019). Minimising production costs gives us the following equations for notional demand for factors of production. This is applicable to any and all economic activities, but in order to simplify the algebra the sectoral index is omitted here:

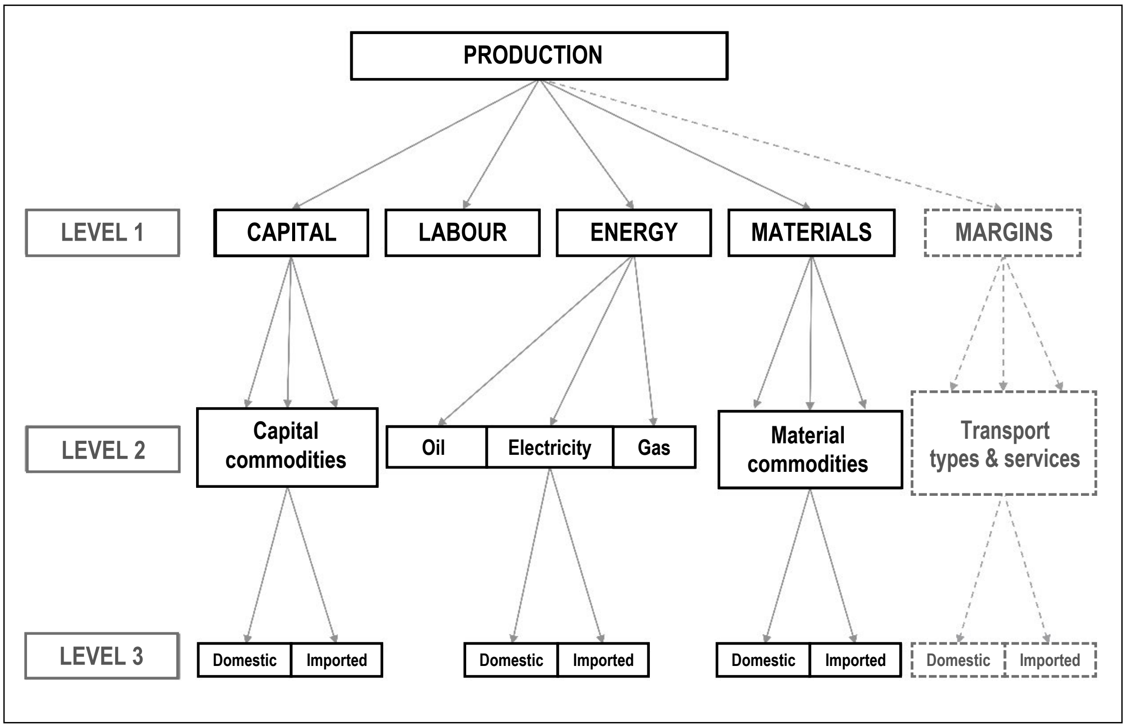
$$\Delta \log\left(FP_{j,t}^{n}\right) = \Delta \log\left(Y_t\right) - \Delta \log\left(PROG\_FP_{j,t}\right) + \Delta SUBST\_FP_{j,t} \quad (9)$$

$$\Delta SUBST\_FP_{j,t}^{n} = -\sum_{\substack{j'=1 \\ j\neq j'}} \eta_{j,j'}\, \varphi_{t-1}^{j'}\, \Delta \log\left(\frac{C_{(j',t)}^{FP}}{C_{j,t}^{FP}}\right), \quad (10)$$

where $\varphi_{j,t-1} = \left(C_{j,t}^{FP};FP_{j,t-1}\right) / \left(\sum_{j} C_{j,t}^{FP};FP_{j,t-1}\right)$ and $j = K,L,E,M$

where FP_j^n is the notional demand for an input j, $\eta_{j,j'}$ is the substitution elasticity between pairs of inputs j and j', $PROG\_FP_{j,t}$ is technical progress relevant to this input j, C_j^{FP} is the cost/price of the input j and Y is the level of production for the sector in question.

Figure A2 – **Structure of production in the ThreeME model**



In keeping with the data from the national accounts, ThreeME supposes that all commodities could be produced by more than one sector. For example, electricity can be produced by several sectors: nuclear, wind power, etc. The output from each sector is defined by the following equations:

$$Y_{c,a} = \varphi_{c,a} YQ_c \quad (11)$$

$$Y_a = \sum_c Y_{a,c} \quad (12)$$

where YQ_c is aggregated domestic production of the commodity c. It is determined by demand (final and intermediate consumption, investment, public spending, export and inventory variation). $\varphi_{c,a}$ Is thus the proportion of the commodity c produced by the sector a (where $\sum_a \varphi_{c,a} = 1$) and Y_a is the aggregated output of the sector a.

Capital and Investment Equations

In ThreeME, investment depends on expected production, past trends, substitution phenomena and a corrective mechanism, which ensures that companies reach their notional level of fixed capital stock in the long term. Fixed capital stock is subtracted from investment using the standard capital accumulation equation.

$$\Delta \log\left(IA_t\right) = \theta_1^{IA}\ \Delta \log\left(Y_t^e\right) + \theta_2^{IA}\ \Delta \log\left(IA_{t-1}\right) + \theta_3^{IA} \times d\left(SUBST\_K\right) + \theta_4^{IA}\left(\log\left(K_{t-1}^n\right) - \log\left(K_{t-1}\right)\right) \quad (13)$$

$$K_t = \left(1-\delta^K\right)K_{t-1} + IA_t, \quad (14)$$

where IA is investment, Y^e expected production, K and K^n real and notional capital stocks, $SUBST\_K$ a variable combining the substitution phenomena between capital and the other inputs, and δ^K the rate of capital depreciation. We also impost the constraint $\theta_1^{IA} + \theta_2^{IA} = 1$ in order to ensure that the stationary equilibrium path does in fact exist. This specification is a compromise between the empirically observed short-term trend and the cohesiveness of the model in the long term. As seen in the MESANGE econometric model (Klein & Simon, 2010), it is common practice to estimate an investment equation rather than a capital stock equation. There are several reasons for this. Firstly, the chronological data series for capital stock are often unreliable. Secondly, estimates often do a better job of representing short-term trends in investment. In particular, they allow us to avoid capital destruction phenomena (negative investment) which are rare in practice, as companies generally prefer to wait and allow for the technical depreciation of their equipment assets. Contrary to MESANGE, however, we suppose that investment depends on the difference between the real and notional capital stocks. This ensures that the real capital stock converges towards its notional level with time. In the long term, the model is thus consistent with the "function of production" theory which holds that there is a direct relationship between production levels and capital stock (not capital flow).

Salary Equation

Various studies have shown that theoretical arguments and empirical estimates do not make it easy to choose between two specifications. Nonetheless, specification differences have significant implications for the definition of the Non-Accelerating Inflation Rate of Unemployment (NAIRU), and thus on the inflationary tendencies and long-term properties of macroeconomic models (Blanchard & Katz, 1999). In ThreeME, we chose a general specification which incorporates the Phillips curves and *Wage Settings* (WS). This supposes that notional nominal wages $\left(W_t^n\right)$ are positively dependent upon expected consumer prices $\left(P_t^e\right)$ and the productivity of labour ($PROG\_L_t$), and negatively dependent upon the unemployment rate $\left(U_t\right)$:

$$\Delta \log\left(W_t^n\right) = \rho_1^W + \rho_2^W\ \Delta \log\left(P_t^e\right) + \rho_3^W\ \Delta \log\left(PROG\_L_t\right) - \rho_4^W U_t - \rho_5^W \Delta U_t. \quad (15)$$

Alternatively, this ratio could be identical to the Phillips curve or the WS curve, depending on the values of the selected parameters (Heyer *et al.*, 2007; Reynès, 2010). The Phillips curve applies when $\rho_4^W > 0$, while the WS supposes that $\rho_4^W = 0$. In order for the model to have a coherent stationary state in the long term, the WS curve must also impose the constraints identified by Layard *et al.* (2005): unit-indexing of wages to prices and productivity: $\left(\rho_2^W = \rho_3^W = 1\right)$ and $\rho_1^W = 0$.

Household Consumption Equation

In the standard version of the model, consumption decisions are modelled using the utility function of the *Linear Expenditures System* (LES), generalised to give non-unitary substitution elasticity between goods (Brown & Heien, 1972). Household spending on each type of good varies (more or less) proportionally to their income:

$$\Delta \beta_{c,t}^{EXP} = \left(1-\eta^{LES\_CES}\right) \Delta \frac{PEXP_{c,t}}{PEXP_t^{CES}} \quad (16)$$

$$PEXP_t^{CES} = \left(\sum_c \beta_{c,0}^{EXP}\ PEXP_{c,t}^{\left(1-\eta^{LES\_CES}\right)}\right)^{\frac{1}{1-\eta^{LES\_CES}}} \quad (17)$$

Price and Margin Rate Equations

Production prices for each sector are set at their lowest level, applying a margin to the unit cost of production (including the cost of labour, capital, energy and other forms of intermediate consumption):

$$PY_t^n = CU_t\left(1+TM_t\right) \quad (18)$$

$$\Delta \log\left(1+TM_t^n\right) = \sigma^{TM}\left(\Delta \log\left(Y_t\right) - \Delta \log\left(Y_{t-1}\right)\right) \quad (19)$$

$$TM_t = \lambda^{TM}\ TM_t^n + \left(1-\lambda^{TM}\right)TM_{t-1}, \quad (20)$$

where PY_t^n is the notional price, CU_t the unit cost of production and Y_t the level of production. TM_t and TM_t^n are the real and notional margin rates, respectively.

The notional price equation is the only price equation derived from economic behaviour: supposing that the demand upon companies is negatively correlated to their prices, we can easily demonstrate that the optimal price corresponds to a margin rate on the margin cost of production. The margin rate equation reflects the fact that returns to scale are diminishing in the short term. As a result, an unexpected increase in production leads to higher marginal production costs, and thus to higher notional prices.

Other prices are defined in accounting terms, starting with production prices and applying an adjustment process:

$$\log PY_t = \lambda_0^{PY} \log PY_t^n + \left(1-\lambda_0^{PY}\right)\log PY_{t-1} + d\log PY_t^e \tag{21}$$

$$d\log PY_t^e = \lambda_1^{PY}\, PY_{t-1}^e + \lambda_2^{PY}\, PY_{t-1} + \lambda_3^{PY}\, PY_{t-1}^n. \tag{22}$$

Household Demand Equations

In the standard version of the model, consumption decisions involving choices between different products are modelled using the utility function of the *Linear Expenditures System* (LES), generalised to give non-unitary substitution elasticity between commodities. An LES specification supposes that a certain portion of consumption (NCH_c) in the reference year is autonomous, or essential, and thus that the relationship between income and consumption is not linear. This specification makes it possible to distinguish between consumption of essential commodities and other goods and services:

$$\left(CH_c^n - NCH_c\right) PCH_c = \varphi_c^{MCH}\left(CH^{VAL} - PNCH\ NCH\right), \tag{23}$$

where $\sum \varphi_c^{MCH} = 1$ and CH_c^n corresponds to the notional level of consumption of a given commodity c, PCH_c is its price, and φ_c^{MCH} the share of non-essential consumption as a proportion of total non-essential consumption (in value terms). This ratio is constant if the substitution elasticity between commodities is equal to one (the Cobb-Douglas hypothesis). In this case, (Cobb-Douglas utility function with no autonomous spending), expenditure will fluctuate proportionally to income. If we use a CES function where the substitution elasticity is η^{LESCES}, the marginal propensity to spend will vary in response to relative prices, following the specification:

$$\Delta \log \varphi_{c,t}^{MCH} = \left(1-\eta^{LESCES}\right)\Delta\left(\log \frac{PCH_{c,t}}{PCH_t^{CES}}\right) \tag{24}$$

$$PCH^{CES} = \left(\sum_c \varphi_{c,t_0}^{MCH}\, PCH_c^{1-\eta^{LESCES}}\right)^{\frac{1}{1-\eta^{LESCES}}}. \tag{25}$$

International Trade Equations

The price of a locally-produced commodity is a weighted average of the production prices (indexed against a) which went into producing that commodity. For example, the electricity price is a weighted average of the prices charged by the various electricity producing sectors. The price paid by the end user (consumers, government, sectors, rest of the world) also includes commercial margins and transport, as well as all taxes less subsidies. Combining these prices with import prices, we get the average price for each commodity, as paid by the end user.

$$\Delta \log\left(X_{c,t}\right) = \Delta \log\left(WD_{c,t}\right) + \Delta SUBST\_X_{c,t} \tag{26}$$

$$\Delta SUBST_{X_{c,t}^n} = -\eta^X\ \Delta \log\left(\frac{P_{c,t}^X\ TC_t}{P_{c,t}^W}\right), \tag{27}$$

where $WD_{c,t}$ is global demand and $P_{c,t}^W$ the price. $P_{c,t}^X$ is the export price, which depends on production costs and reflects the price-competitiveness of domestically-produced goods. TC_t is the exchange rate; η^X is price-elasticity (presumed to be constant). We assume that substitution between domestic and imported goods is not perfect (Armington, 1969).

Demand for imported goods can be written:

$$A_{c,t}^M = \varphi_c^{A^M}\ A_c \tag{28}$$

$$\varphi_c^{A^M} = \frac{1}{1+\dfrac{AD_c}{AM_{c,t_0}}\, e^{SUBST_c^{AM}}} \tag{29}$$

$$\Delta\left(SUBST_c^{AM}\right) = -\eta_c^{AM}\ \Delta\left(\log PAD_c - PAM_c\right) \tag{30}$$

and as a result:

$$A_{c,t}^D = \left(1-\varphi_c^{A^M}\right) A_c, \tag{31}$$

where $A_{c,t}$ represents the demand for each type of use (intermediate consumption, investment, consumption, public spending, exports, etc.) for a commodity c, while $P_{c,t}^A$ is the price. $A_{c,t}^M$ and $A_{c,t}^D$ are, respectively, the imported products and domestic products wanted for each type of usage A, with $P_{c,t}^{AM}$ and $P_{c,t}^{AD}$ their respective prices. The substitution elasticity η_c^{AM} for a type of use A of a given commodity c can vary, which allows for a high degree of flexibility. With regard to demand for use in intermediate consumption or investment, equations are constructed for each sector a, and these equations are specified for each $A_{c,a,t}$.

A full description of the model is available online at www.threeme.org.

Calibration of the Parameters

For the purposes of this article, the parameters were calibrated using the following values and, with the exception of the values pertaining to autonomous consumption of energy products (specific to this study), the same values were also used in Malliet *et al.* (2020).

Table A2-1 – **Calibration of behavioural parameters**

Elasticity parameters	Value
Elasticity of substitution between factors of production ($\eta_{F,F'}$)	0.5
Elasticity of substitution between energy sources ($\eta^{NRJ}_{c,c'}$)	0.2
Elasticity of substitution between modes of transport ($\eta^{TRSP}_{c,c'}$)	0.2
Elasticity of substitution between consumer goods (η^{LESCES})	0.5
Armington elasticity ($\eta_{c,c'}$)	0.8
Elasticity between margin rate and demand (σ^{TM})	0.75

Table A2-2 – **Calibration of adjustment parameters**

Adjustment parameters	Value
Price equations	
λ^{PY}_0	0.5
λ^{PY}_1	0.7
λ^{PY}_2	0.1
λ^{PY}_3	0.2
Salary equations	
ρ^W_1	0
ρ^W_2	1
ρ^W_3	1
ρ^W_4	0
ρ^W_5	0.6
Equations for factors of production	
λ^L_0	0.5
λ^E_0	0.9
λ^M_0	0.9
λ_1	0.7
λ_2	0.1
λ_3	0.3
Investment equations	
θ^I_2	1
θ^{IA}_3	0.5
θ^{IA}_4	0.05
Production equations	
λ^{Ye}_0	0.7
λ^{TM}	0.5
Household consumption equations	
λ^{CH}_0	0.6
λ^{CH}_1	0.7
λ^{CH}_2	0.1
λ^{CH}_3	0.2

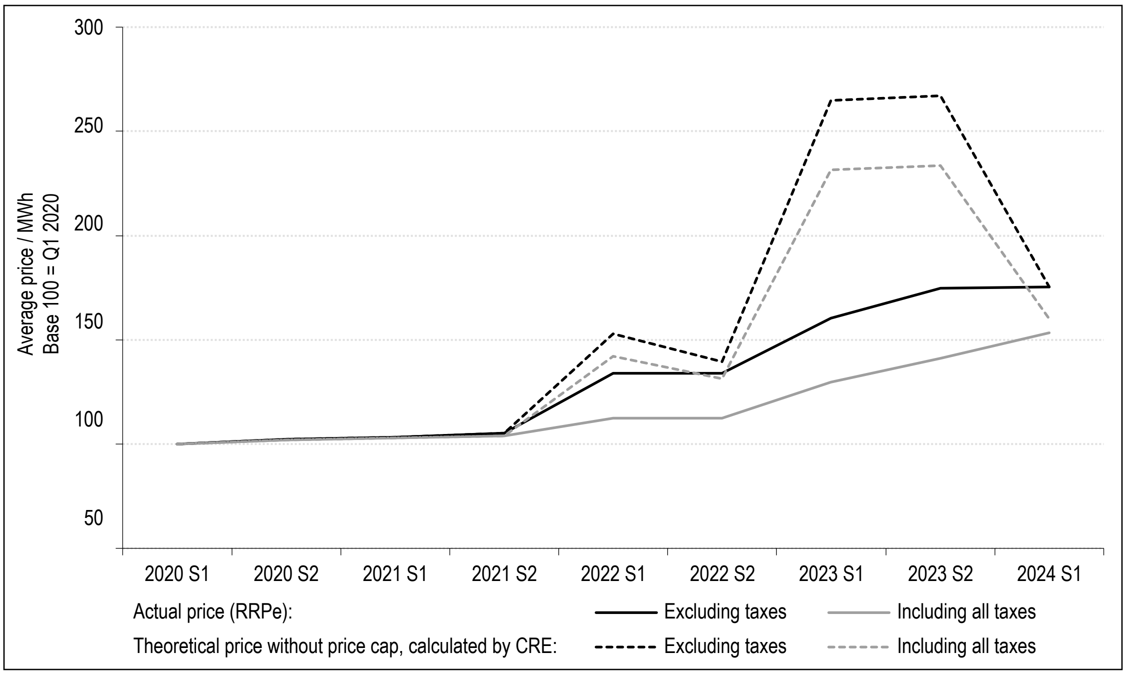
Table A2-3 – **Calibration of autonomous energy consumption**

Proportion of autonomous consumption	Value
Electricity consumption (φ_{cele}^{NCH})	0.25
Gas consumption (φ_{cgas}^{NCH})	0.4

APPENDIX 3

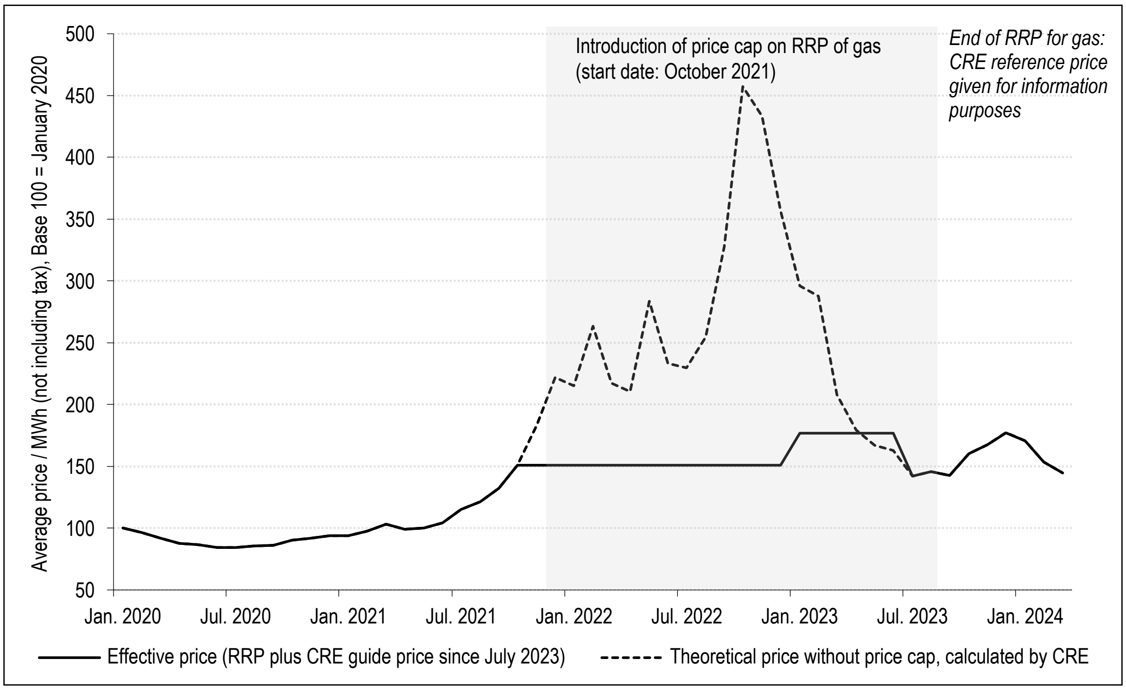
AVERAGE RRP FOR GAS

Figure A3-I – **Comparing average RRP for electricity, with and without tax**



Source: CRE, authors' calculations.

Figure A3-II – **Average RRP for gas**



Source: CRE, authors' calculations.