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The incidence of VAT reforms in electricity markets: Evidence from Belgium ☆

Jean Hindriks[a], Valerio Serse[b,*]

[a] UCLouvain, LIDAM/CORE, Economics School of Louvain, Voie du Roman Pays 34, Louvain-la-Neuve, Belgium
[b] Compass Lexecon, Brussels and UCLouvain, LIDAM/CORE, Belgium

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A B S T R A C T

In April 2014, the Belgian government reduced the VAT rate on the electricity price from 21% to 6% to support low-income families. In September 2015, the tax cut was repealed, and the VAT rate was reinstated to 21% in the context of a change of government. This paper investigates the impact of such temporary and (plausibly) exogenous VAT reform on the Belgian electricity market. We study the pass-through of the VAT reform to electricity prices and the effect of this (exogenous) price change on electricity demand. We estimate the VAT pass-through on residential electricity prices by a *difference-in-differences* method, using business electricity prices (not subject to VAT) as a control group. Our findings reveal that both the tax cut and the tax hike were entirely shifted to the electricity price (100% pass-through). To assess the impact of the VAT change on demand, we perform a counterfactual demand analysis of the electricity flowing monthly over the grid at the network operator level. Exploiting VAT and non-VAT related price variations, our results show a price elasticity of residential demand for electricity between -0.09 and -0.17. Interestingly, we also find that demand reacted quickly and symmetrically to the VAT cut and the subsequent VAT hike.

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1. Introduction

In order to promote competitiveness and employment, the Belgian Federal Government decided to reduce the Value-Added Tax (VAT) rate for the supply of electricity to household consumers from 21% to 6% from 1 April 2014 (Law of 15 May 2014 implementing the Pact for Competitiveness, Employment and Recovery) .[1] As of 1 September 2015, the federal government decided to reverse this VAT reduction early and charged 21% VAT again.

This paper investigates the impact of such (plausibly exogenous) VAT reform on the Belgian electricity price and demand. We also provide novel evidence on the possible (a)symmetry in both the VAT pass-through rates and the demand elasticity using the two tax change instances. Indeed, the VAT reforms involved first a tax decrease to 6%, followed by a tax increase

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* Corresponding author.
E-mail addresses: jean.hindriks@uclouvain.be (J. Hindriks), valerio.serse@uclouvain.be (V. Serse).

[1] Royal Decree of March 21, 2014 amending Royal Decrees Nos 4 and 20 concerning value added tax.

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to 21% within 17 months. This provides the opportunity to test for symmetry in the price and demand responses to the tax cut and tax reversion over a limited time interval under otherwise similar electricity market conditions.

The quality of the tax incidence analysis depends on the plausible exogeneity of the tax reforms. In a Royal Decree of 21 March 2014, it was decided to cut the VAT rate on electricity supply to residential customers from 21% to 6% conditional on evaluating this tax reform by September 2015. The VAT cut was part of the general "competitiveness and employment pact" of the ruling government. The VAT cut was intended to benefit the low-income households and reduce inflation, which given the Belgian automatic indexation, translates into wage costs. The inflation rate was reduced by 0.4 pp, indexation was postponed by four months, and the net budgetary cost of the reform was estimated at 536 million euros in 2015 (BFP, 2015).

Then the newly elected government proposed in July 2015 a new "tax shift" plan. This plan intended to shift the tax base partly from labor to consumption as part of a strategy to reduce wage costs and promote employment. The tax shift plan involved the VAT rate increase on electricity from 6% to 21% in September 2015. Although both VAT reforms were claimed to be motivated by the same concern for labor cost and employment, they were probably driven by political reasons (see also Benzarti et al., 2020; Fuest et al., 2018; Castanheira et al., 2012 who showed that political factor is the main driver of tax reforms). Therefore, the two successive VAT reforms can be seen as plausible exogenous shocks driven by political considerations from two different ruling governments, which were not linked to economic conditions in the electricity market. Also, the reality of the 2015 "tax shift" is that the lower income tax does not offset the extra consumption taxes in the household budget constraint.[2]

We estimate the VAT pass-through to the residential electricity price by employing a *difference-in-differences* method. We use as a control group the electricity price for professional consumers (firms) to assess the price incidence of the VAT changes for residential users (households). VAT is not taken into account for professional consumers, as it is recoverable for them. The assumption is that the residential electricity price would have followed the same trend as the professional electricity price without the VAT changes. Our sample with prices for the consumer and firm segments displays parallel trends both before (January 2013-March 2014) and after (October 2015-December 2016) the VAT changes (see Fig. 3).

The results show that the VAT cut was entirely shifted to the residential electricity price. This result is in line with recent studies showing that the cost of emission permits in Europe is almost entirely shifted to electricity prices (Fabra and Reguant, 2014; Hintermann, 2016). However, there is a lack of evidence about the pass-through of VAT to retail electricity prices. The earlier empirical work has mostly focused on the incidence of excise taxes rather than sales taxes and VAT for a wide variety of markets.[3] Nevertheless, in the EU, the VAT is the largest source of tax revenue (on average 30% of total tax revenue), so it matters to understand its price incidence. There is also currently a debate on using VAT as part of the recovery plan for Europe.

Some empirical studies estimate the pass-through of sales/VAT taxes in other markets. Doyle and Samphantharak (2008) and Marion and Muehlegger (2011) studied the incidence of sales taxes on fuel in the United States, with a pass-through close to unity and symmetric response to a temporary moratorium on a 5% gasoline tax increase. Carbonnier (2007) showed that two large VAT cuts in France (on housing repairing services and new car sales) were partly shifted into consumer prices. Similarly, Kosonen (2015) found that the pass-through rate of the VAT cut on hairdressing services in Finland was 50%. Benedek et al. (2020) studied various tax reforms in the Eurozone and showed that the standard VAT rate was usually entirely shifted, whereas the reduced VAT rates were partly shifted. In contrast, we find that the VAT cut to 6% was fully shifted to electricity prices.

This literature typically identifies the VAT pass-through by looking at consumer price changes before and after the VAT reform while controlling for the price evolution in other markets.[4] However, finding a reliable control group for VAT changes is rather difficult. This is because the VAT affects the whole market to which it is applied. Furthermore, even if the VAT change affects only one sector, there is a risk of a cross-price effect on the closest sectors producing substitute products. We address these concerns by adopting a difference-in-differences approach that uses business prices as a counterfactual scenario. Business prices are not subject to VAT but have the same cost components as residential prices. Moreover, these two tariffs are not substitutable since households cannot switch to business prices. Without controlling for business prices, we would have reached the misleading conclusion that the VAT cut was (slightly) under-shifted to consumer prices.

We also test for possible asymmetries in the VAT incidence since we observe both a VAT cut and an increase of the same size within a limited time interval (17 months). To our knowledge, there are few similar "symmetric tax reforms" in Europe with two (significant) VAT changes of the same size but in opposite directions. There is the Finland VAT cut on hairdressing of 14 percentage points in January 2007 and the subsequent VAT increase of 14 percentage points in January 2012. Using Beauty salons as a control group, Benzarti et al. (2020) showed that the pass-through rate for VAT increase

[2] The scope of the tax shift was rather limited with a VAT increase mostly on electricity and with extra excise taxes on alcohol. Those extra consumption taxes represented around 20% of the total tax shift. Another 20% was measures based on cost saving in the social security. The rest was extra tax revenue on capital income and other non fiscal revenues. One half of the tax shift revenue was distributed to firms to reduce employment cost, and the other half was used to increase household disposable income. The net impact on household income was rather limited given the savings in the social security. Therefore, because the VAT mostly hit electricity prices and not the full bundle of consumption goods, the change in relative electricity price is of a first order whereas the income effects is of a second order.

[3] Many works studied excise tax incidence in the context of sodas (Berardi et al., 2016; Cawley and Frisvold, 2017; Etilé et al., 2019), cigarettes (Harding et al., 2012; DeCicca et al., 2013) and alcoholic beverages (Kenkel, 2005; Shrestha and Markowitz, 2016; Hindriks and Serse, 2019).

[4] Benedek et al. (2020) use as counterfactual price the one of the same commodities sold in other European countries that did not change their VAT rate. Carbonnier (2007) uses the price index for non-treated industries. Kosonen (2015) uses the price of other labour-intensive services.

is double that of the VAT cut. Another symmetric VAT reform (of smaller magnitude but more comprehensive) was in Hungary, with the standard VAT cut of 5 percentage points in January 2006 (for all commodities excluding diesel and gasoline) and a subsequent VAT increase of 5 percentage points in July 2009. Using neighbouring countries as a control group, Benzati et al. (2020) found evidence of (persistent) asymmetric pass-through rates with a much stronger price incidence of VAT increases. They also provided strong evidence of asymmetric pass-through rates for other commodities (except for the communication, household furnishing, equipment, and maintenance sectors)[5] from other European "asymmetric" VAT reforms, where the VAT cuts and hikes were of unequal magnitudes.

The analysis of Benzati et al. (2020) suggests that asymmetric VAT incidence is widespread and not specific to some commodities, challenging standard (static) tax incidence theory (Hindriks and Myles, 2013). However, it is always possible that the asymmetric pass-through rate is either due to the asymmetric VAT changes or to different economic conditions underlying the VAT cut and increase.[6] Our electricity market analysis does not find any asymmetry in tax shifting between the VAT cut to 6% and the subsequent VAT hike to 21%. Our difference-in-differences analysis suggests that the VAT changes were entirely shifted to the consumer price. This result is certainly expected for the regulated component of the electricity bill (transmission and distribution costs), but it is not evident for the other unregulated components (energy cost and providers fees).

Several factors can help explain the perfect shifting of the VAT rate on electricity price. First, the retail electricity market is quite competitive. Under perfect competition, complete shifting is a likely scenario even though under-shifting is also possible. Another factor is the salience of the reform. The cut was widely advertised in the media. This suggests that the tax reform was under scrutiny, with public pressure to shift the VAT cut entirely to the consumers.[7] Lastly, many electricity contracts are based on publicly available indexation formulas (variable contracts) and are closely monitored by the regulator. Since the VAT rate is directly applied to these formulas, providers had to modify them to not shift the VAT cut entirely to consumers. This could have been either too costly or difficult to justify to both consumers and the regulator.

Another contribution of this work is to estimate the impact of the VAT changes on residential demand for electricity. The firm segment may not be a reliable control group for the demand analysis because the professional demand for electricity does not necessarily follow the same dynamic patterns as the residential demand.[8] We then perform a counterfactual analysis based on predicted residential demand (using observed covariates such as sunlight, temperature, solar production, and monthly-distributor fixed effects). We study the monthly demand for electricity at the network distributor level, controlling for changes in other determinants of energy use during the period. We find that the VAT cut from 21% to 6% generated a 2% increase in electricity demand.[9]

Exploiting different sources of price variation (VAT and non-VAT), we find a price elasticity of residential demand for electricity between −0.09 and −0.17. This range aligns with recent estimates based on quasi-experimental price variations (see, for instance, Ito, 2014; Deryugina et al., 2020).[10] We also provide evidence about the symmetry of the demand response to the price cut and the price hike using the two tax changes. Demand responded to the same extent (albeit in a different direction) to a price cut and a price hike of the same magnitude. This finding has important implications for price-based climate policies and energy conservation. It indicates that VAT hikes are entirely shifted to consumers and can be effective in reducing energy use.[11] In contrast, a reduction in the VAT rate is likely to reduce electricity prices, thus increasing electricity consumption.

Lastly, we show that consumers responded quickly to the VAT reform, increasing their demand one month after the VAT cut. This evidence contrasts with the previous literature, suggesting that consumers react slowly to changes in electricity prices.[12] The VAT reform was announced early in the media, and the pass-through was perfect, making the reform more salient. Such salience of the tax reform may, in turn, induce consumers to react more quickly to price changes (Chetty et al., 2009; Ito et al., 2018). Combining the flat electricity rates with the salience of the VAT reform makes it simple for the consumer to understand the actual change in the electricity price. The short-run demand elasticity may also be explained

[5] Electricity sector is not covered in their analysis.

[6] In Finland, the VAT cut in January 2007 was during the Finish economic recession whereas the VAT increase in January 2012 was during the Finish economic recovery.

[7] Given the (linear) two-part tariff for electricity price (with fixed fee and a flat rate), the marginal rate is independent of consumption and equal to average rate. There is no possible confusion on the price (as in Shaffer, 2020) with the consumers mistakenly interpreting the average price as the marginal price. If the VAT cut was not fully shifted, it would then have been easily detected by the consumer. Tax salience favors full shifting of tax cut.

[8] Our professional electricity demand data aggregate demand at the network level (DSOs) for all those businesses such as restaurants, bars, laundries, shops, etc. Professional electricity demand differs from residential demand. The difference in demand is observable in the data, with the business consumption displaying different seasonal patterns than the residential demand (see Table C2 in Appendix C, where we run a Placebo test on the business demand).

[9] In the Appendix B we perform an event study regression on the impact of the VAT reform on electricity consumption and we obtain similar results as in the counterfactual demand analysis.

[10] While the VAT price variation is plausibly exogenous, it is less so for the other price variations. So we should interpret with more caution the demand response related to non-VAT price changes.

[11] Around the 30% of the electricity generation in Belgium is based on fossil fuels, mainly natural gas (Eurostat, 2020).

[12] Price elasticity of electricity demand tends to increase over time because energy consumption depends on the stock of the owned appliances. While this is fixed in the short-run, this can be changed in the long-run as a function of the present and expected future prices.

by the impact of economic incentives on energy-efficient use.[13] Moreover, we find that the increase in electricity demand is concentrated in sunnier and warmer periods when energy is less needed for heating and home lighting.[14] This seasonal variation in demand elasticity can indicate that residential electricity is essential in winter rather than summer.

The structure of the paper is as follows. Section 2 describes the institutional details of the Belgian electricity market. Section 3 presents the data and summary statistics. Section 4 estimates the VAT pass-through rate for the two tax changes and tests the pass-through symmetry using a difference-in-differences approach. Section 5 estimates the demand effect (without a control group) using the two price change instances. We also estimate the demand elasticity and its symmetry between price cut and hike. Section 6 concludes.

2. Belgian electricity market

Belgium has opted for the so-called ownership unbundling model, where the Transmission (TSO) and Distribution System Operators (DSOs) are completely separated from the generation and retail sectors by means of independence requirements implemented in Belgian law.

The generation sector is composed of firms generating electricity power at the source. Electricity can be generated in different ways. The traditional system uses nuclear power or fossil fuels, while others use renewable energy sources such as solar, wind, or hydroelectric power. Since the generation market has been liberalized, any company can build a power plant and operate in this sector upon receiving the required authorisations. The leading electricity producer in Belgium is Engie Electrabel, followed by EDF Luminus and EON. Nuclear power is still the primary source of electricity generation, although its share is declining over time. During the period of our analysis, nuclear power accounted for roughly 50% of the total domestic generation. In 2020, this share declined to 39% (Elia, 2021). The second-largest source of electricity is gas, which in 2020 amounted to 34% of the total electricity generation. The rest of the electricity is generated from renewable sources. Renewable energy is supported by a system of green certificates that are issued for each kilowatt-hour of electricity produced. These certificates can be sold on the certificates' market. Their demand consists of energy suppliers and electricity users that have to respect an obligation quota.

The scope of the *Transmission system operator* (TSO) is to transmit energy from the transmission grid (and from abroad) to the distribution network. Belgium has a single TSO, *Elia System Operator*, which operates on the entire public transmission system and is subject to a special legal framework. The TSO is appointed for a 20-year period by the federal Energy Minister, and its tariffs are fully regulated. The TSO must propose its tariffs to the national regulator (Commission for Electricity and Gas Regulator - CREG), which may pre-approve them for a four-year regulatory period. Tariffs are generally approved if they follow the pricing criteria established in advance by the regulator.[15] Once tariffs are approved, they typically remain unchanged during the entire four-year period. Nevertheless, these tariffs can be changed at any time, subject to the regulator's approval. The VAT is directly applied to transmission tariffs. Therefore, any VAT change must be passed on to transmission tariffs entirely.

Distribution system operators (DSOs) manage the electricity distribution network for a specific territory. They transmit the electricity from the grid to the final users at the supplier's request. Moreover, they are responsible for providing new network connections and the reading of the electricity meter. In Belgium, DSOs are grouped in organizations, like ORES in Wallonia and Eandis in Flanders.[16] The DSOs can adjust the distribution tariff according to the environment in place to recover the distribution cost. This means that distribution tariffs can vary across Belgian localities. Distribution tariffs are updated annually and submitted to the approval of the regional regulators.[17] As for transmission tariffs, VAT changes are also automatically passed through to distribution tariffs as they are fully regulated.

Retailers (service providers) sell the electricity to end-users and bill their energy use. In Belgium, the retail market is liberalized. Energy retailers buy the energy from a generator (or on the power markets). However, generators and retailers could also be controlled by the same company. The four major retailers are Engie Electrabel, EDF Luminus, Lampiris, and Eni. Although the market is fully liberalised, the federal government introduced various price control measures on electricity retailers. In 2013, the government granted the right to terminate supply contracts without penalty to protect households and SMEs. Furthermore, from 2012, the national regulator can monitor indexation formulas of variable contracts to limit excessive price hikes.[18] This means that retailers are free to set their energy prices, but the regulator can intervene if a price increase is considered too high. Importantly, in the context of the VAT reform, retailers did not have any explicit

[13] For instance, Ito et al. (2018) use a follow up survey of their economic incentive experiment on electricity demand to show that consumers respond to economic incentives by using their existing electric appliance (air conditioners, electric heaters, IT material, washers, etc.) more efficiently.

[14] This is in contrast with Ito et al. (2008) showing with RCT that residential electricity demand responds to the same extent to the same announced peak-hour pricing hike during the summer and the winter experiments.

[15] Our VAT incidence analysis is undertaken for the Transmission tariff period January 2013-december 2016 and follow the same principles (i.e., a fair remuneration mechanism, combined with incentive components for certain expenses and revenues of the TSO).

[16] For instance, Eandis is comprised of seven Flemish electricity distribution system operators.

[17] These are: Brugel (Brussels capital region), Vreg (Flanders), and CWaPE (Wallonia).

[18] In particular, between 2013-2017, the government used a "safety net" mechanism to limit the price of the energy component upward. Under this mechanism, energy suppliers can index variable energy prices every three months. The CREG monitors indexing and compares possible price increases with those of consumers of the same type in neighboring countries.

obligation to pass the VAT cut entirely to consumers. Therefore, whether the VAT cut was passed on or not to consumers is instead an empirical question.

The electricity bill paid by the end-user is the sum of the energy, transmission, and distribution components, including the taxes, surcharges, and VAT.[19] The electricity price in Belgium can be considered as a two-part tariff. There is a fixed fee (paid to the retailer regardless of the consumption level), and a flat rate for each kWh consumed. For most contracts in Belgium, the price per kWh does not change with the consumption level (i.e., flat rate tariffs). Nevertheless, the price per kWh can change across contract types, as they can be offered to different consumption profiles based on their annual electricity consumption. The energy component represents 17% - 20% of the average bill, which is the remuneration for generators and retailers.

To protect against energy price fluctuation, consumers can choose between a fixed price contract (65% of consumers) and a variable price contract (35% of consumers). The unit price (€c/kWh) of energy usage is fixed during the contract period in the fixed contract. However, all other components of the contract may vary. That is, distribution, transmission, and taxes can change during the contract period. In the variable contract, the unit price (€c/kWh) for energy consumption is indexed at regular intervals (typically quarterly) during the contract period according to an indexation formula. Consumers can terminate supply contracts (including fixed contracts) without penalty.[20]

The tariffs of network operators for transmission and distribution are also levied on the kWh consumed and have a flat rate structure. DSOs are active locally, and their prices can vary over localities. In this study, we have data for a total of 20 distribution grid operators.[21] Although these fees can vary across space, they do not vary across different service providers and types of electricity contracts in a given locality. That is, every network operator charges the same price to every retailer locally. The rest of the electricity bill comprises federal and local energy taxes, which are also levied on the kWh consumed with a flat rate structure. The shares of the various components may vary depending on the type of customer considered, distribution areas, regions, and retailers. In this work, we consider the marginal price of electricity. Hence, we consider only those taxes levied per kWh consumed. These include both regional and federal levies. VAT is applied to each component of the electricity bill. Few exemptions include the connection fee in Wallonia, the contribution for the energy fund in Flanders, and the federal contribution. Electricity taxes are levied on the final supply of electricity to the consumer. The retailer is responsible for the payment of the tax and all other remunerations.

3. The data

The price data is provided by the Belgian Energy Regulator (CREG), which collects the monthly prices of the most common electricity contracts. This data refers to the two major electricity providers in Belgium: Engie Electrabel and Luminus. In 2016, they accounted for 79% of the market share in Brussels, 61% in Flanders, and 71% in Wallonia (CREG, 2016). Each of them offers two types of contracts. Luminus offers *Click* and *A+*, while Electrabel offers *Easy Fixed* and *Easy Indexed.* Each of these four contracts has both the firm and household versions. The firm and household versions can have different prices but mainly differ because of the VAT. Household contracts are subject to VAT, while firm contracts are not. Therefore, we have information on eight price series. Four are subject to VAT (household segment), while the other four are not (firm segment).

We consider the price series that refers to the most standard consumption profiles and have a flat rate for consumed kWh. These prices refer to a consumption profile of 3500 kWh/year for households and 50,000 kWh/year for firms (SMEs), which correspond to the vast majority of Belgian Households and SMEs. These consumption profiles are those used by the Belgian Energy Regulator (CREG) to monitor electricity prices. In this study, we focus on the price per kWh consumed only. This is because the fixed fee remained stable over the years for each contract, changing only twice according to the two VAT rate changes. The VAT changes were entirely shifted to the fixed fee component.

The price per kWh varies across retailer and contract types. For the *Luminus Click* and *Easy Fixed* contracts, the price per kWh paid by the client is fixed for a given period (this can be from 1 up to 3 years). However, that does not prevent the client from switching (costlessly) to a better contract offered by the same or a different service provider. Price comparators are publicly available. If the prices are fixed for the client who has already signed a contract, they change monthly for any new client (Newcomer contract). Hence, the price series we consider for these two contracts do vary monthly. The other contracts are instead indexed. Their price can change for both new and old customers according to an indexation formula. The price, however, can be indexed just every quarter, which means that these prices can only change four times per year. If the contract is designed for a household, the VAT is applied to each price component (tax component included). The total monthly electricity price is the sum of all these tax-inclusive price components plus the annual fixed fee. Since we have data for about 20 network operators and eight contracts, we have 160 price observations for each month from January

[19] The average electricity bill for residential consumers in Brussels is divided roughly as 1/3 energy, 1/3 transmission-distribution and 1/3 taxes and surcharges (CREG, 2017).

[20] In 2021, the national regulator provides price benchmarking across retailers. For a standard consumption of 3,500 kWh, the ratio between the cheapest and most expensive offer (in euro/year) was 274/509 in Flanders, 307/524 in Wallonia and 251/465 in Brussels (CREG, Infographic for households, March 2021. Available at https://www.creg.be/sites/default/files/assets/Prices/InfographResEn.pdf).

[21] However, in the consumption analysis we drop observation about eight of them, as we do not have enough data about consumption for these distributors before the VAT reform. These distributors are mostly small ones.

Table 1
Summary statistics – electricity price.

	21% VAT period(01/13 – 03/14)		6% VAT period(04/14 – 08/15)		21% VAT period(09/15 – 12/16)	
Price component	*Households*	*Firms*	*Households*	*Firms*	*Households*	*Firms*
Energy	7.41	6.53	6.45	6.49	6.71	5.94
Green Quota[1]	1.84	1.52	1.84	1.74	2.46	2.03
Distribution	9.92	8.25	9.09	8.61	11.77	9.74
Transmission	2.40	1.96	2.49	2.34	2.87	2.37
Other Taxes	0.64	0.53	0.51	0.50	0.53	0.51
Total	22.21	18.80	20.38	19.68	24.35	20.59

Notes: Price components are expressed in €cent/kWh. These prices are the average across contracts and network operators included in the sample. For Household prices, each component includes the VAT.
[1]The green quota refers to a contribution for the production of renewable energy, which firms pass to consumers. Firms are obliged to purchase a minimum number of green certificates to support the development of renewable energy sources.

2013 to December 2016. Table 1 below summarizes the data in our sample, distinguishing between the electricity prices for households and firms during the VAT reforms.

The summary statistics reveal a significant drop in the electricity price throughout the temporary VAT cut at 6%. However, the costs of the different components may also have changed over that period, sometimes under the influence of different policy changes. To identify the impact of the VAT change on prices, we should carefully consider the counterfactual evolution of electricity prices in the absence of the VAT change. We will do that using the change of the price for firms as a counterfactual.

Turning to consumption data, they are provided by *Synergrid*, the Belgian federation of network operators. The consumption data consists of the monthly kWh flow over the electricity grid through each distribution system operator (DSO). Hence, the unit of observation is the monthly electricity consumption at the DSO level. We have information for about 15 DSOs over four years (January 2013 – December 2016), making a total of 720 observations. These DSOs are the largest ones, serving the majority of the Belgian population. This measure does not account for the electricity consumed by households producing their electricity (e.g., through solar panels). Although the auto production of electricity is becoming increasingly popular in Belgium (partly due to generous subsidy schemes),[22] most residential electricity consumption is still flowing through the grid.[23] For the demand analysis, we match the price data to each DSO. Regulated tariffs and surcharges are specific to the given DSO. However, as energy costs can vary across service providers but not DSO, we use the average energy tariffs across service providers in our sample.

Our data can distinguish electricity demand for different consumption profiles. Each DSO has information about the flow of electricity passing through its network every quarter of an hour thanks to reading meters located at the main injection points. This flow of electricity is tracked for four different consumption profiles: businesses with a power supply <56 kVA; businesses with a power supply ≥ 56 kVA; residential with a usage ratio night/day < 1.3; residential with a usage ratio nigh/day ≥ 1.3. This distinction is possible because each of these profiles has a different electrical connection to the grid,

For residential demand, we consider households with a usage ratio night/day below 1.3.[24] This consumption profile is standard with average annual electricity consumption of around 3500 kWh, corresponding to our price series. We have data about the aggregated consumption and the number of households (i.e., European Article Numbering - EAN) for each DSO monthly. This allows us to compute the average monthly consumption of a Belgian household in every DSO's area. The consumption data also allows separating the consumption of households benefiting from social tariffs. This is possible as a separate social supplier furnishes these households. A distinction that is important as these households face different prices.[25] Overall, this data corresponds to the monthly electricity consumption of 3.5 million Belgian households (75% of Belgian households) aggregated at the DSO level.[26]

To control for demand fluctuations driven by seasonal patterns and other covariates, we also collect data about the hours of sunlight, the degrees-days,[27] and the amount of electricity that is auto produced (i.e., the electricity not flowing over the grid). Table 2 above shows a general decrease in electricity demand over time. However, various factors affecting electricity demand did vary as well over the same period. The degrees-days measures tend to decrease over the three periods, meaning that there was probably less need for energy to heat buildings given the higher outside temperature. The level of sunlight increased during the last period, suggesting that less electricity for house lighting was needed. The level of auto production

[22] See Boccard and Gautier (2020) and Gautier and Jacqmin (2020) on the impact of subsidies for solar panels on PV installations in the Belgian region of Wallonia.

[23] Recent evidence also suggests that generous policies promoting investment in renewable energy can also affect long-term electricity prices. In particular, Bushnell and Novan (2018) find that the dramatic increase in solar capacity in California decreased mid-day prices, while increasing shoulder hour prices.

[24] This corresponds to the Synthetic Load Profile S21 provided by *Synergrid*.

[25] The price series for social tariffs is displayed in Fig. A1 in the appendix. These tariffs are fully regulated and tend to vary much less than normal prices.

[26] In our sample, around 80.000 households are subject to social tariffs.

[27] The degrees-days compare the mean (the average of the high and low) outdoor temperatures recorded for a location to a standard temperature. It is a measure of the amount of energy needed to reach standard temperature in average building. This data is also taken from *Synergrid*.

Table 2
Summary statistics – electricity demand.

Variable	21% VAT period(01/13 – 03/14)	6% VAT period(04/14 – 08/15)	21% VAT period(09/15 – 12/16)
Consumption (kWh)	267.81	255.90	245.39
Auto production (TWh)	1.46	1.80	1.75
Sunlight	122.42	122.19	156.33
Degrees-days	224.20	188.29	142.94

Notes: Consumption is the average monthly consumption per Household (EAN code in kWh). The hours of sunlight and degree-days are the monthly average over the mentioned period. Auto production is a yearly estimate at the national level and is expressed in TWh (it is not seasonally adjusted).

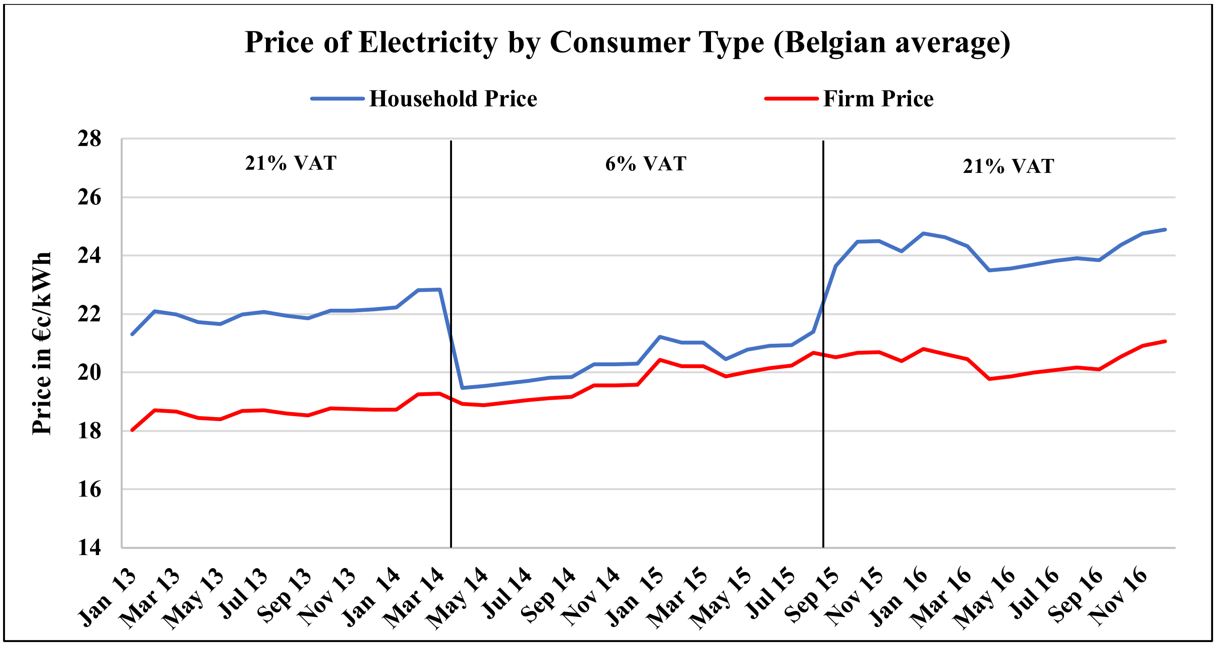

Fig. 1. Price of electricity by consumer type (Belgian average).
Data source: Authors, with price data from the CREG.

of electricity increases from 2014. This could partially explain the decrease in electricity demand in the network grid over the last two periods (from April 2014 to December 2016).

4. VAT pass-through to electricity prices

We estimate the impact of the temporary VAT reform on the residential electricity price through a difference-in-differences approach, which uses the price of electricity paid by firms as a control group. The reason is that households are subject to the VAT on electricity price, while firms are not. Hence, we assume that the residential electricity price would have followed the same evolution as the business electricity price without the VAT changes. As illustrated in Fig. 1, the business electricity price is a reliable control group for this analysis. We see the parallel pre-treatment and post-treatment trends. The two groups share the same cost components and are provided mainly by the same electricity providers. The main difference in the final price per kWh is the VAT, which is only paid by households. Hence, the business electricity price offers a reliable counterfactual for the evolution of residential prices without the two VAT changes.

The period of analysis for the VAT pass-through goes from January 2013 to December 2016. The VAT cut from 21% to 6% occurred in April 2014, and it was then repealed in September 2015. The use of the electricity price for firms as the counterfactual scenario assumes that nothing else apart from the temporary VAT cut affected the price of electricity differently across these two groups. Given that the time window between the two VAT changes is relatively narrow (17 months), we could easily verify that no other significant policy changes within that period could have affected the price of electricity differently between the treated and control group.

Another critical assumption is the absence of spillover effect of the VAT changes on the control group prices. This assumption seems quite realistic as these two types of electricity services are not substitutable. Households cannot subscribe to a business tariff. This means that a change in relative price cannot lead households to switch to a business contract, in-

Table 3
Impact of VAT reform on total electricity price.

Variable	Simple difference	Diff-in-diffs
Intercept	2.95***	2.77***
(β_0)	(0.01)	(0.01)
Household Tariff		0.17***
(β_1)		(0.00)
VAT_{cut} (β_2)		0.01**
		(0.00)
$VAT_{pass-through}$ (β_3)	0.94***	1.00***
	(0.03)	(0.04)
Pass-through Rate	94%	100%
C.I.	[0.89 – 0.99]	[0.93 – 1.07]
R^2	0.23	0.31
Observations	3840	7680

Notes: *, ** and *** indicate statistical significance at the 0.10, 0.05, and 0.01 level, respectively. Heteroskedasticity-Robust standard errors are in parenthesis.

creasing the electricity price for firms due to higher demand.[28] Fig. 1 suggests that the business electricity price did not vary significantly between the two VAT changes. Fig. 1 indicates average prices among service providers. In the tax pass-through analysis, we will exploit both the cross-sectional and time variations in prices.

4.1. VAT pass-through to electricity price

We estimate the impact of the temporary VAT cut on the total price of electricity in Belgium by means of a difference-in-differences regression. We use the total price of electricity paid by professional consumers as a control group during the period of the temporary tax change. The model is specified as follows:

$$LN(P)_{ijt} = \beta_0 + \beta_1 HH_j + \beta_2 VAT_{cut} + \beta_3 LN(1+\tau)_t + \varepsilon_{ijt}. \tag{1}$$

where $LN(P)_{ijt}$ is the natural log of the electricity price of provider i for consumer profile j in month t. The consumer profiles j are either residential or business. β_0 is the intercept of the model and measures the average business price (control group). The variable HH_j is a dummy equal to 1 if the price concerns a household tariff and 0 otherwise. Its coefficient β_1 captures the average difference between the firm price and the household price. VAT_{cut} is a dummy variable equal to 1 during the period of the temporary VAT cut and 0 otherwise. That is, from April 2014 until August 2015. Its coefficient β_2 measures the evolution of the electricity price for firms during that period, which is the counterfactual scenario for household prices. As the dependent variable is expressed in logarithmic terms, this coefficient approximates the percentage change in the electricity price for firms during the period of the VAT cut, which is equal to $e^{\beta_2} - 1$.

$LN(1+\tau)_t$ is the natural log of the VAT multiplicator, where τ is the current VAT rate in month t. (i.e. either 0.06 or 0.21) The coefficient β_3 can be interpreted as the difference-in-differences estimator of the VAT pass-through rate. This coefficient measures the pass-through rate of the temporary VAT reform by considering the evolution of the electricity price for firms as the counterfactual scenario. More specifically, the VAT pass-through rate can be defined as follows:

$$\beta_3 = \frac{\partial LN(P)}{\partial LN(1+\tau)} = \frac{\Delta P/P}{\Delta\tau/(1+\tau)}$$

The model is estimated for the period 1 January 2013 – 30 December 2016. Table 3 below shows the OLS estimates for the parameters of the difference-in-differences regression outlined in Eq. (1). From these estimates, we can infer the causal impact of the temporary VAT change on electricity prices. The level of observation is the price per kWh charged by each service provider for each contract type. As distribution and transport charges vary across network operators, we have a total of 160 monthly observations (4 contracts × two client types × 20 distributors) covering four years. The coefficient β_1 shows that household prices are generally higher than firm prices. The coefficient β_2 approximates the percentage change in the price of the control group during the period of the temporary VAT cut. Its estimate indicates that firm prices increased by 1% during this period. This means that without VAT cut, household prices would have increased by this amount. The coefficient β_3 indicates the pass-through rate of the VAT reform. The estimation suggests that the VAT change was entirely shifted to electricity prices, with a pass-through rate equal to 100%.

Table 3 also shows the result of a simple difference estimator for the VAT pass-through. This table suggests that controlling for the change in business prices affects the results. We would have mistakenly concluded that the VAT was slightly

[28] A possible concern is that the demand response to the VAT change could have affected T&D tariffs for both firm and consumer segment. This would invalidate our analysis since the VAT would also affect the control group (professional consumers). Nevertheless, as also discussed later in Section 5, T&D rates are plausibly exogenous in our period because the transmission tariff was set for four years before the VAT cut, while distribution tariffs are set yearly and are exogenous to demand up to capacity constraints. As shown by the demand analysis, the demand response was moderate, and it is unlikely that distributors reached the capacity constraints.

under-shifted with a simple difference estimator. We also re-run regression (1) to check whether the perfect shifting conceals some heterogeneity in tax shifting across different service providers and contract types. However, we do not find any heterogeneity across providers and contracts. Hence, confirming the result of perfect tax shifting of the VAT change on electricity prices.

The total electricity price is the sum of different price components. Two of these components have regulated prices, as they are provided by network operators that are local monopolies. These are the prices for the transmission and distribution (T&D) of electricity. The energy regulator regulates these prices, so network operators cannot respond freely to the VAT change. As a result, the VAT cut must have been entirely shifted to the price of these components.

Service providers, however, are in a competitive market environment. They can choose how to shift the tax change on the price of the electricity that they provide. More specifically, they charge consumers the cost of the energy supplied and the *green quota* for renewable energy. The VAT may have been shifted differently on these two price components. Therefore, we re-run regression (1) to estimate the VAT pass-through for these two components separately. However, we find no difference in VAT shifting between these two price components.[29]

4.2. Symmetry in vat pass-through

The temporary VAT reform provides an opportunity to test for asymmetries between shifting the tax cut and the consecutive tax hike. Although the results above suggest a complete shifting of the VAT reform, we check whether this finding still holds when studying the two events separately. We want to test whether the VAT cut in April 2014 and the successive VAT hike in September 2015 were both perfectly shifted to electricity prices. We estimate a difference-in-differences regression when the two VAT reforms are considered separately to test this hypothesis. The model estimated is as follows:

$$LN(P)_{ijt} = \beta_0 + \beta_1 HH_j + \beta_2 VAT_{cut} + \beta_3 LN(1+\tau)_t + \beta_4 VAT_{hike} + \beta_5 \left(VAT_{hike} * HH_j\right) + \varepsilon_{ijt}. \tag{2}$$

Regression (2) is like regression (1). $LN(P)_{ijt}$ is the natural log of electricity price of provider i for consumer profile j in month t. β_0 is the average price in the control group during the period before the temporary VAT reform. While β_1 measures the difference between this price and the average household price during the same period. The interpretation of β_2 and β_3 are the same as in regression (1), with the only difference in the baseline period here being the pre-VAT cut period (January 2013 – March 2014).[30] The VAT_{hike} is a dummy variable equal to 1 for the post-VAT hike period. Its coefficient β_4 approximates the percentage price difference in the control group between the pre-treatment period and the post-treatment period with VAT reinstatement at 21%. This would be the counterfactual scenario for household prices if the VAT change did not occur. The coefficient β_5 is the difference-in-differences estimator of the VAT reinstatement at 21% on household electricity prices. Given that we are using the pre-VAT-cut treatment as the baseline, β_5 is testing whether household electricity prices revert to their pre-treatment level. If that is the case, the coefficient β_5 should be equal to zero.

We estimate regression (2) on the total price of electricity and the energy and the green quota component separately. The results displayed in Table 4 suggest that the impact of the two VAT changes on electricity prices was symmetric and that both tax changes were entirely shifted. The pass-through of the VAT cut on the total electricity price is equal to 99%, while that of the energy components is 102%. The pass-through for the green quota is around 100%, but it is not statistically significant.[31]

The perfect and symmetric shifting of the VAT changes to residential electricity prices contrasts with existing evidence about VAT pass-through in other markets (see, for instance, Kosonen, 2015; Benedek et al., 2020; Benzati et al., 2020). Several reasons could account for that symmetric and perfect shifting. First, the electricity market is quite competitive. Under perfect competition, full or under-shifting are possible scenarios, while over-shifting is not feasible. Second, the magnitude and salience of the reform were widely advertised in the media. This may have increased public attention on electricity bills, forcing suppliers to shift the VAT cut entirely to the consumers. Third, the adjustment cost in electricity pricing may have also contributed to this result. One-third of electricity contracts are based on indexation formulas that are publicly available and closely monitored by the regulator. The VAT rate is directly applied to these formulas. This means that electricity suppliers had to modify their indexation formula if they did not want to shift the tax change on the consumer prices entirely. That could have been too costly or difficult to justify to the regulator.

5. The demand response

In this section, we study the impact of the temporary VAT reform on electricity consumption. The fact that the VAT change was significant and plausibly exogenous to the consumer demand provides us the opportunity to estimate the price elasticity of electricity demand. Since consumers experienced a substantial decrease in price and subsequent price increase, we can also test for possible asymmetries in the demand response to opposite price changes.

[29] The results of this estimation are shown in Table A1 in the Appendix.

[30] In regression (1) the baseline period was the period outside the VAT cut: before April 2014 and after September 2015.

[31] We find that this result is due to some heterogeneity in shifting patterns across regions. If we estimate the pass-through separately for each region, we find a statistically significant pass-through around 108% for the regions of Brussels and Wallonia. In contrast, we find an under-shifting around 86% for Flanders. Nevertheless, these results should be taken with caution because the green quota amounts to only a few cents per kWh consumed.

Table 4
Test for asymmetries in VAT pass-through.

Variable	Total	Energy	GreenQuota
Intercept	2.73	1.67***	−0.29
(β_0)	(0.01)	(0.06)	(0.20)
Household Tariff	0.17	0.13***	0.18**
(β_1)	(0.00)	(0.03)	(0.08)
VAT_{cut}	0.05***	0.00	0.14*
(β_2)	(0.00)	(0.03)	(0.08)
$VAT_{pass-through}$	0.99***	1.02***	1.01
(β_3)	(0.04)	(0.24)	(0.85)
VAT_{hike}	0.08***	−0.18***	0.42***
(β_4)	(0.00)	(0.03)	(0.08)
Household Tariff	0.00	−0.01	0.01
* VAT_{hike}	(0.01)	(0.04)	(0.11)
(β_5)			
R^2	0.37	0.25	0.07
Observations	7680	384	1152

Notes: *, ** and *** indicate statistical significance at the 0.10, 0.05 and 0.01 level, respectively. Heteroskedasticity-Robust standard errors are in parenthesis. The price of the energy component varies across contract and client types, but it is homogeneous across network operators. Each of the four contracts has both the firm and household versions, so we have eight different energy price observations for each month over 48 months (384 observations). The green quota can vary across the 3 Belgian regions, which can have different renewable energy quotas requirements. So, we have 24 different green quotas over 48 months (1152 observations).

The challenge of estimating the impact of the VAT reform on electricity consumption is to isolate the effect of the tax change from other events that might have occurred over the same period. Unlike the VAT pass-through analysis, we cannot reasonably perform a difference-in-differences analysis using business consumption as a control group. Indeed, we do not expect business consumption to evolve in parallel with residential demand before and after the VAT changes. Business consumption displays different seasonality patterns than residential consumption.

We will estimate the impact of the VAT reform on residential electricity demand following a counterfactual demand approach. We estimate a model of electricity demand exclusively during months with a regular VAT rate at 21% to predict the counterfactual demand for months subject to the reduced VAT rate at 6%. The impact of the VAT reform on electricity demand is then estimated by measuring the difference between the actual electricity demand (under VAT 6%) and the predicted demand in the counterfactual scenario (under VAT 21%). This model and its results are discussed in Section 5.1 below.[32]

Section 5.2 estimates the price elasticity of electricity demand by exploiting the VAT reform as a plausibly exogenous shock to the consumer demand in electricity prices. We then investigate the symmetry in the price elasticity of electricity demand to a price cut and a price hike following the VAT cut and its repeal.

Section 5.3 studies the time heterogeneity in the demand response to the VAT reform through an event study regression with leads and lags of the VAT cut in April 2014. This analysis shows how electricity demand responded to the VAT change over time. In addition, this analysis also allows checking for the absence of any anticipation effect to the VAT change since the VAT reform was only announced one month before its implementation.

5.1. Predicting counterfactual demand

Our first approach consists of predicting the counterfactual demand for electricity. This allows us to estimate the impact of the VAT cut on electricity consumption by computing the difference between the actual electricity demand and the counterfactual one. We do that by estimating a model to explain electricity consumption through variations in its most relevant determinants. Since electricity consumption is highly seasonal, accounting for seasonality helps us considerably in predicting the counterfactual scenario.

In particular, we estimate the following model:

$$C_{jt} = \gamma_{jt} + \beta_1 sunlight_{jt} + \beta_2 degrees.days_{jt} + \beta_3 auto.prod_{jt} + \varepsilon_{jt}. \quad (3)$$

where C_{jt} is the total electricity consumption (measured in kWh per capita) in the area supplied by distributor j in month t. The level of observation is the monthly consumption in the area covered by each distributor. γ_{jt} is the distributor-monthly fixed effect, which measures the average consumption level in the area supplied by distributor j for a given month of the year. These fixed effects are crucial for our analysis since they capture the large seasonality in electricity demand.

[32] We also estimate the impact of the VAT reform on electricity demand through an event study regression, which controls for seasonality and other determinants of electricity consumption. Although this is equivalent to a single difference estimator, we have two different instances of a price change that can help us identify the causal impact of the VAT cut on electricity demand. The results of this analysis are consistent with the counterfactual demand approach, and they are presented in Appendix B.

Table 5
Coefficients for predicting counterfactual demand (Model 3).

Variable	(1)	(2)	(3)	(4)
Sunlight	−1.04***	−1.04***	−0.34	−0.34***
(β_1)	(0.16)	(0.08)	(0.27)	(0.05)
Degree-days	0.80***	0.80***	0.52***	0.52***
(β_2)	(0.07)	(0.03)	(0.14)	(0.02)
Auto production	−0.12***	−0.12***	−0.17***	−0.17***
(β_3)	(0.03)	(0.01)	(0.03)	(0.05)
Distributor FE	No	Yes	No	Yes
Monthly FE	No	No	Yes	Yes
Monthly-Distributor FE (γ_{jt})	No	No	No	Yes
R^2	0.67	0.93	0.72	0.99
Observations	435	435	435	435

Notes: *, ** and *** indicate statistical significance at the 0.10, 0.05 and 0.01 level, respectively. Heteroskedasticity-Robust standard errors are in parenthesis. The number of observations is 435 for all specifications. This is lower than the 720 observations used in the event study because we do not consider the VAT cut period. The model is estimated on the period January 2013 – February 2014 and October 2015 – December 2016.

Table 6
Impact of VAT cut on electricity demand.

(Average Difference between Actual and Counterfactual Consumption)			
Period	% difference	95% Lower C.I.	95% Upper C.I.
VAT rate 21%	0.01%	−0.01%	0.02%
VAT rate 6%	2.35%	1.94%	2.76%

Notes: The percentage difference between actual and counterfactual consumption is computed using model (3) estimates, which are displayed in column 4 of Table 5.

The variables $sunlight_{jt}$ and $degrees.days_{jt}$ control for weather fluctuations. The former indicates the hours of sunlight in a month, while the latter measures the degrees-days (*Degrés-jours Synergrid*).[33] We expect to find that the sunnier the month, the lower the electricity consumption. For colder months and hence for high degree-day levels, we expect higher electricity demand. The variable $auto.prod_{jt}$ is the amount of electricity auto-produced by Belgian households. Because we estimate the demand for electricity from the grid, the coefficient of this variable should be negative, as the higher the amount of electricity auto-produced, the lower the electricity demanded from the grid.

We estimate demand model (3) only during months with the VAT rate at 21%, thus leaving out the VAT cut period (April 2014-August 2015). In our basic specification, we also leave out the "shoulder" months (one month before the treatment, March 2014, and one month after the treatment, September 2015). Hence, the estimation period is January 2013 – February 2014 and October 2015 – December 2016.[34]

Column 4 of Table 5 displays the estimated coefficients for the demand model (3). The other columns show the estimated coefficients using alternative specifications for the distributor or monthly fixed effects. Interestingly, the estimated coefficients are highly significant, and the R-squared is very high. This means that the model can capture variations in electricity demand, especially thanks to the high seasonality and cross-sectional differences in consumption.

Using the estimated coefficients from the demand model (3), we can compute the counterfactual electricity demand by fitting the model to the months subject to the VAT at 6% (excluded from the estimation). As a result, the counterfactual electricity demand for each month can be computed as:

$$\hat{C}_{jt} = \hat{\gamma}_{jt} + \hat{\beta}_1 sunlight_{jt} + \hat{\beta}_2 degrees.days_{jt} + \hat{\beta}_3 auto.prod_{jt}.$$

where $\hat{C}_{jt}$ is the predicted demand for distributor j in month t, while $\hat{\gamma}_{jt}$ and $\hat{\beta}_n$ are the estimated coefficients. Fig. 2 below compares the evolution of the actual electricity demand and the counterfactual demand, which we have estimated for the whole period from January 2013 until December 2016.

The figure above shows that actual and counterfactual consumption are very close during the estimation period. That is the one with a VAT rate of 21%. This is not surprising since the model was estimated using those observations. Interestingly, we can see "abnormal" consumption immediately after the VAT cut at 6% in May 2014 - September 2014. Then, from October 2014, the actual and predicted consumptions do not differ. However, the actual consumption is systematically different from the prediction during July 2015 - August 2015, just before the VAT cut was repealed. Table 6 displays the average difference between actual and predicted (counterfactual) consumption during both the 21% and 6% VAT periods. The difference between these two series indicates the unexpected change in residential demand associated with the VAT cut.

[33] As explained before in the data section, the degrees-days is a measure of the amount of energy needed during a month to heat an average building.
[34] In the robustness section (Appendix C), we show that our results are similar when using different estimation periods.

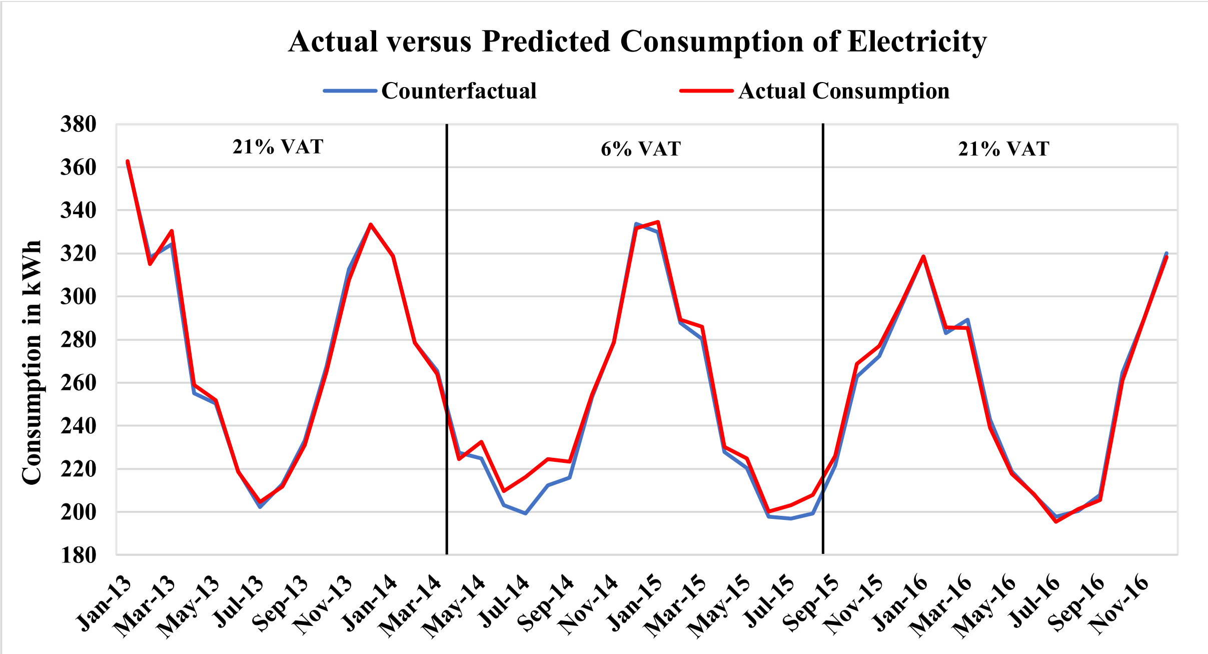

Fig. 2. . Actual versus predicted consumption of electricity.
Data source: Authors, with data from Synergrid. Consumption in kWh is the average across distributors.

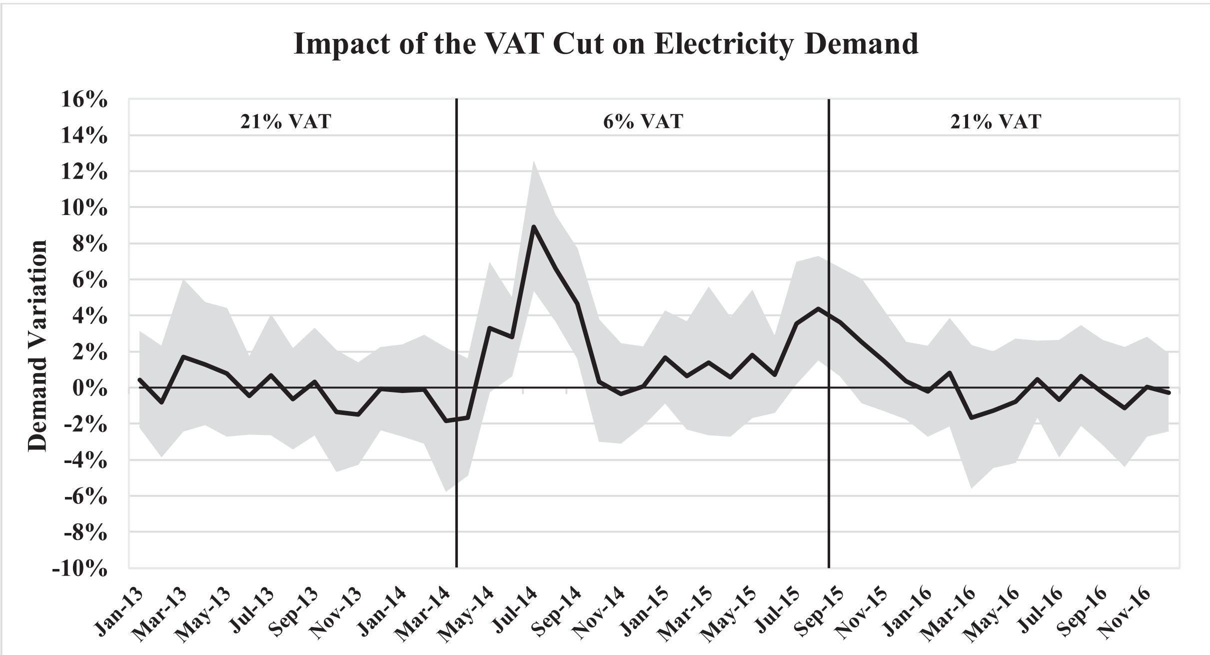

Fig. 3. . Impact of the VAT cut on electricity demand.
Data source: Authors, with data from Synergrid. The series shows the gap between actual and counterfactual consumption.

Our estimates suggest that the VAT cut increased electricity demand by 2.35% on average. Nevertheless, as shown in Fig. 2, this result conceals a significant heterogeneity in the timing of the demand response. Firstly, households reacted quickly to the price decrease, increasing consumption just one month after the VAT cut. Secondly, the change in electricity demand is concentrated during the summer months (with low residential demand), while there is no significant effect in other periods.

Fig. 3 above illustrates this result by showing the percentage deviation from predicted demand. The shaded area is the 95% confidence interval of this difference. The figure shows that actual consumption was significantly higher than predicted demand in the period May 2014 – September 2014. The actual consumption was also significantly higher in July 2015 and August 2015, just before the VAT cut was repealed.

Since the identification of the demand response does not rely on a control group, we perform several robustness checks to validate our analysis. The first check is based on the event study regression provided in Appendix B. The second set of checks focuses on validating the counterfactual model by changing the estimation or prediction period length. These tests confirm the results of the counterfactual analysis presented in this section. Furthermore, we run various placebo tests by predicting the counterfactual demand in periods with no VAT cut, but we do not find any significant demand changes during these periods.[35] These robustness checks and their results are presented in Appendix C.

5.2. Demand elasticity

The exogenous variation in electricity prices due to the VAT reform allows us to estimate the price elasticity of electricity demand. The estimates can be retrieved from the results of regression (3), as we know the change of both price and demand after the VAT changes. However, the VAT reform was the principal but not the only source of price variation in the data. Changes in electricity prices over the sample period also occur due to updates in regulated components, such as transmission and distributions, and due to some other shocks to energy prices. Therefore, we can estimate the demand elasticity by exploiting the different sources of (plausibly exogenous) price changes since we can disentangle the type of price variations.

The change in price due to the VAT change is likely to be exogenous to household demand because both reforms were implemented for reasons outside the electricity market.[36] This constitutes a good source of price variation to identify the demand elasticity. Some studies have also argued that changes in regulated tariffs can be considered as exogenous sources of price variations (see Bernstein and Griffin. 2006; Paul et al., 2009). In our case, the energy regulator sets prices for the transmission and distribution of electricity. Transmission tariffs are set for four years, while distribution tariffs can change yearly. Over the sample period, they slightly increased, possibly reflecting inflation adjustments. These tariffs are cost-based and should not depend on demand up to capacity constraints. Assuming that regulated tariffs are exogenous to electricity demand, their variations can also be used to identify demand elasticity.[37]

The residual variation in electricity prices is due to changes in energy cost, which is not regulated. These price changes can be due to temporal or permanent cost shocks in producing and selling electricity to residential consumers. Nevertheless, they can also be related to changes in demand-side conditions because service providers are free to set their prices. In this case, price changes are not entirely exogenous to household demand and can, therefore, constitute a spurious source of price variation.

We extend our estimation of the demand elasticity by exploiting these different sources of price variation. In particular, we identify the demand elasticity by using either: i) the VAT change; ii) the VAT change plus the regulated price change; or iii) all price changes. More specifically, we estimate the demand elasticity by estimating the following demand model:

$$LN(C)_{jt} = \gamma_{jt} + \beta LN(Price)_t + \sum_n \theta_n X_{njt} + \varepsilon_{jt}. \tag{4}$$

where $LN(C)_{jt}$ is the natural log of the (average) electricity consumption (measured in kWh per capita) in the area supplied by distributor j during month t. γ_{jt} are the distributor-monthly fixed effects. The price variable $LN(Price)_t$ is either: i) the log of the VAT rate, $LN(1+\tau)_t$, when we exploit the VAT change only; ii) the log of the regulated price (VAT included); or iii) the total electricity price. Lastly, X_n is the set of covariates used in the (counterfactual) demand model (3). These variables include the amount of electricity auto produced by households, the degree-days (*Degrés-jours Synergrid*), and the hours of sunlight during each month. The coefficient β is the price elasticity of electricity demand.

We estimate regression (4) by standard OLS procedure. We also estimate the first two specifications (VAT and Regulated price) through a two-stage least square (2SLS) procedure, where in the first stage, we instrument the price by either a dummy variable for the VAT cut or by the regulated price (net of VAT) plus the VAT dummy. We estimate regression (4) on both standard and social tariffs.[38] Social tariffs are homogenous across the country and are entirely regulated.[39] They can be changed every quarter. However, they are also subject to VAT, and hence they have been impacted by the temporary

[35] We also run an additional placebo test, based on the event study regression, using the business electricity consumption during the period of VAT changes. Since business electricity prices are not subject to the VAT, business demand should not be affected by the VAT reform. Hence, we check whether the electricity demand for firms changed similarly to the one for households during the period of VAT changes, as this would suggest that non-VAT factors can drive our results. The results of this analysis are presented in Appendix C and shows that business demand did not vary with the VAT change.

[36] As mentionned in the introduction, these two reforms were motivated by political considerations rather than electricity market conditions.

[37] Although the assumption of exogeneity of regulated tariffs seems plausible, this would be invalid if a persistent increase in demand leads a distributor up to its capacity constraint. This will allow the distributor to negotiate higher fees for the coming year (or even anticipate it). We think that this scenario is unlikely, but we cannot rule it out. Therefore, our estimates based on regulated tariffs are just illustrative and should be taken with caution.

[38] However, as social tariffs are fully regulated, estimating the demand elasticity using the VAT change and the regulated price component is equivalent to exploiting all price variation in the data.

[39] Although these tariffs are homogeneous across regions, the final price paid by consumers subject to social tariffs can vary due to some additional regional surcharges. Like the *Cotisation Fonds Energie* in Flanders and the *redevance de raccordement* in Wallonia.

VAT reform (VAT change was entirely shifted on social tariffs). These tariffs only apply to low-income households under a specific set of legal conditions. As we can identify the electricity consumption subject to these tariffs, we can estimate the demand response of low-income households and compare it to the rest of the population.

The results of this analysis are displayed in Table 7 below. The β coefficient for price indicates the estimate for the demand elasticity. According to the different model specifications displayed in Table 7, the demand elasticity estimates can range from −0.09 to −0.17. Interestingly, Table 7 highlights that (low-income) households subject to social tariffs have a demand elasticity similar to other households. When exploiting all price variations in the data, this is equal to −0.14 and −0.12, respectively (see columns 5 and 8).

Although these estimates seem quite low, they are significant and in line with other studies based on quasi-experimental price variations. For instance, Ito (2014) estimates the demand response to both average and marginal electricity price variations induced by a discontinuity in electricity service areas in California. He finds that the demand is sensitive to average prices rather than marginal prices, with a demand elasticity of −0.09 four months after the (average) price changes. In our context, we do not disentangle average and marginal prices. In Belgium, the electricity price is a two-part tariff, with the VAT applied to both the price per kWh and the fixed fee. Therefore, the VAT reform changed marginal and average prices to the same extent.[40]

Deryugina et al. (2020) also find a similar demand elasticity following an exogenous drop in electricity prices due to a municipal group-buying policy in Illinois. The municipal aggregation allowed local communities to select new electricity suppliers on behalf of their residents with the approval of a local referendum. This policy led to a significant price decrease in communities that implemented aggregation. They find a demand elasticity that varies between −0.09 and −0.16 within 6 and 12 months, respectively. Again, we get precisely the same range of estimates accounting for VAT and non-VAT related price variations.

As shown in Table 7, if we measure the demand elasticity using the VAT change only, we get the same demand elasticity for standard and social tariffs, equal to −0.17. Interestingly, we get significantly lower demand elasticities when exploiting changes in both the VAT and regulated price components. For standard tariffs, this decreases the demand elasticity from −0.17 to −0.10. Using 2SLS instead of OLS does not affect the coefficients, but it slightly increases the range of the confidence intervals. Hence, these findings suggest that consumers are more sensitive to changes in the VAT rate than changes in other price components.

Two elements could help explain this finding. First, the price variation was very salient because the VAT change was announced and highly visible.[41] Second, given the simple price structure (flat-rate) and the comprehensive application of the VAT rates (on all components of the electricity bill), the change in electricity price was independent of consumption level and proportional to the change in the VAT rate. Changes in other price components may be less transparent since they must be carefully checked in the monthly electricity bill.

The two VAT changes also provide a natural experiment to test for differences in demand response to a price hike and a price cut. This can have interesting implications for price-based climate policies, as they would mainly imply an energy price hike. If consumers have asymmetric responses to price changes of different signs, this must be considered when evaluating the impact of these policies on energy use. Moreover, there is little evidence about the effects of plausibly exogenous price hikes on electricity demand under linear tariffs. This is a relevant issue since, as Ito (2014) and Shaffer (2020) have shown, the flat marginal price is preferable to a non-linear tariff to achieve greater energy conservation.

To investigate the symmetry in demand response to the VAT cut and the VAT hike, we estimate the demand elasticity by allowing it to vary across two periods: from January 2013 to December 2014 and another from January 2015 to December 2016. The aim is to estimate demand elasticities for the VAT cut and the subsequent VAT hike separately. Since the VAT reform was not the only source of price variation, we do not have a perfectly symmetric price change. There is a price drop of −11% in the first period and a price hike of +14% in the second period (this amounts to +12% for social tariffs).

We re-estimate model (4) using the full price variation to control for the asymmetry in price changes and compute the demand elasticity separately for the price cut and the price hike. The results are displayed in Table 8 above. The results suggest that consumers are equally sensitive to price cuts and hikes since their demand elasticity is symmetric. Again, we do not find much difference in demand elasticities across different household types. The demand elasticity for standard tariffs is −0.10, while (low-income) households subject to social tariffs have an elasticity of −0.12. This result can have interesting implications for climate change and conservation policies as consumers with different income levels may react similarly to price-based policy changes.

[40] Shaffer (2020) provide strong quasi-experimental evidence of the notoriously low electricity demand response to price change. When electicity tariffs are non linear, marginal price depends on consumption and consumers do not always know their consumption. They mistakenly use the average price for the marginal price. As result there is no demand response to a marginal price change (such as peak-hour marginal pricing change) when the average price does not vary.

[41] An example of the importance of price salience in the context of electricity bills is provided by Sexton (2015), which finds that consumers enrolling in automatic payment programs become less sensitive to variations in electricity price. Alternatively, Kahn and Wolak (2013) and Ito et al. (2018) find that better informing the consumers on the marginal electricity price induces consumers to respond rationally (i.e., consumers facing higher marginal price reduce their demand and vice-versa).

Table 7
Demand elasticity.

	Standard tariffs (1–5)				Social tariffs (6–8)			
	VAT only		VAT and regulated price		Totalprice	VAT only		Totalprice
Variable	OLS	2SLS	OLS	2SLS	OLS	OLS	2SLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LN(price)	−0.16	−0.17	−0.09	−0.10	−0.12	−0.17	−0.17	−0.14
	(0.01)	(0.03)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
Degree-Days	0.56	0.50	0.56	0.52	0.58	0.55	0.55	0.53
	(0.02)	(0.04)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
Sunlight	−0.48	−0.33	−0.47	−0.30	−0.46	−0.45	−0.44	−0.45
	(0.03)	(0.05)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)
Auto production	−1.59	−1.43	−1.21	−1.14	−1.32	−0.85	−0.85	−0.86
	(0.05)	(0.08)	(0.05)	(0.05)	(0.05)	(0.07)	(0.07)	(0.07)
Elasticity	−0.16	−0.17	−0.09	−0.10	−0.12	−0.17	−0.17	−0.14
C.I.	-[0.19–0.13]	-[0.24–0.10]	-[0.10–0.08]	-[0.13–0.07]	-[015–0.10]	-[0.20–0.13]	-[0.21–0.14]	-[0.17–0.10]

Notes: All coefficients are statistically significant at the 0.01 level. Heteroskedasticity-Robust standard errors are in parenthesis. All models have 720 observations and include interactions between the distributor and monthly FEs (seasonal effect at the distributor level).

Table 8
Symmetry in demand elasticities.

Variable	Standard tariffs	Social tariffs
Demand Elasticity	−0.10	−0.12
(VAT cut)	-[0.13 - 0.08]	-[0.15 - 0.08]
C.I.		
Demand Elasticity	−0.10	−0.12
(VAT hike)	-[0.13 - 0.08]	-[0.15 - 0.08]
C.I.		

Notes: All coefficients are statistically significant at the 0.01 level. Heteroskedasticity-Robust standard errors are in parenthesis. Control variables include distributor FE, monthly FE, and their interaction, as well as all other control variables included in model (4).

5.3. Time heterogeneity in demand response

The economic literature suggests that the demand response to changes in electricity prices is dynamic (see, for instance, Labandeira et al., 2017; Deryugina et al., 2020). The demand elasticity tends to increase over time because consumers need time to change their stock of appliances and their relative energy efficiency (Rapson, 2014; Sahari, 2019). Moreover, electricity prices are complex and not easily visible to consumers (Sexton, 2015). Thus, consumers may take time to realize an actual change in price.

In our context, the price change is likely to be more salient than a usual price change for at least two reasons. First, the VAT changes were large (15ppt change) and widely announced in the media. Second, it was easy to assess the implication on prices given the simple (linear) tariff structure. This means that the demand response to the VAT changes could have been faster than other price changes. The counterfactual analysis of electricity demand suggests that the demand response was almost immediate (within a month after the treatment). Moreover, we also find that most of the variation in demand occurs during summer periods, thus suggesting some relationship between the elasticity of electricity demand and weather conditions.

We explore these dynamics by estimating an event study regression that allows demand to vary monthly during the VAT cut period. The regression estimates the variation in the kWh of electricity consumed during each month of the VAT cut, taking as reference period the one with the VAT at 21%. In practice, we estimate the following regression.

$$C_{jt} = \gamma_{jt} + \sum_{t=-6}^{16} \beta_t [VAT_{cut}]_t + \sum_n \theta_n X_{njt} + \varepsilon_{jt}. \tag{5}$$

where C_{jt} is the electricity consumption measured in kWh per capita for the area supplied by distributor j during month t. We do not specify the dependent variable in log terms as we want to estimate the absolute change in kWh consumed during the reform period. VAT_{cut} is a dummy variable equal to 1 for each month before and after implementing the VAT cut. We consider $t \in [-6,\ 16]$, that is we include six leads and 16 lags from the month of the VAT cut in $t = 0$.[42] The coefficient β_t measures the increase in kWh consumed over each month before and after the VAT reduction at 6%. The baseline period is the one with the VAT at 21%, excluding the six months pre-reform so that we can estimate the leads.

By including the leads up to six months before the VAT cut, we can estimate whether electricity demand increased before the VAT cut. This is a helpful robustness check, as the VAT change was announced one month before its implementation. Thus, we should not observe any demand increase before that period. Instead, the lags indicate how the variation in electricity demand evolved during each month following the VAT cut (and before the subsequent VAT hike 17 months later). All other control variables included in model (5) are the same as model (3).

The results of regression (5) are shown in Fig. 4 below. The figure displays the leads and lags for the VAT cut. They correspond to the β_t coefficients estimated in regression (5). The leads are the change in kWh consumed for each month before the VAT cut up to six months before its implementation in April 2014. The change is estimated relative to the same month average consumption with 21% VAT (except the six months leads before the VAT cut).[43] Since the leads measure the change in consumption between months with the VAT at 21% and the six months before VAT cut (where the VAT was still at the same rate), we would not expect any significant change in consumption during this period. In contrast, the lags identify the change in electricity consumption for each month with VAT at 6% with respect to the average consumption during the same month with VAT at 21%.[44]

[42] The last lag coincides with the month just before the reinstatement of the VAT at 21%.

[43] The (baseline) months with 21% VAT correspond to the period that goes from January 2013 to September 2013 and from September 2015 to December 2016. The months going from October 2013 to March 2014 are not considered as (baseline) months with 21% VAT since they are used to compute the leads.

[44] Fig. 4 displays only the months going from October 2013 to August 2015 because they are the β_t coefficients estimated in regression (5). They corresponds to the variation in kWh consumed for each month with respect to the same month average consumption during periods with 21% VAT. Since the baseline period with 21% VAT is the one going from January 2013 to September 2013 and from September 2015 to December 2016, these months are excluded from the graph.

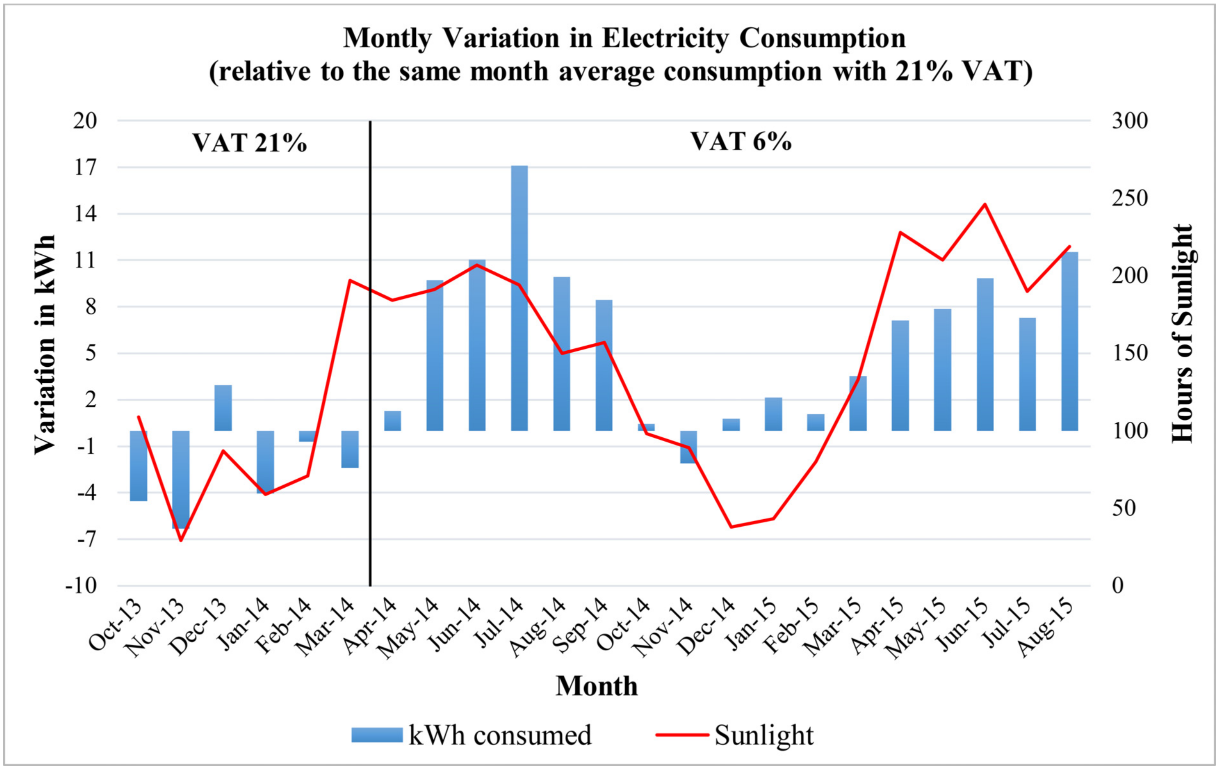

Fig. 4. Montly variation in electricity consumption (relative to the same month average consumption with 21% VAT).
Notes: *The histogram shows the estimates of each monthly $\boldsymbol{\beta_t}$, which are the leads and lags of regression (5). The red curve displays the hours of sunlight during each month.*

Fig. 4 shows that electricity consumption increased almost immediately after the VAT cut (within the month of the treatment). The average monthly increase in electricity consumption during the 6% VAT period was equal to 6.30 kWh, representing roughly a 2% increase in electricity demand. Interestingly, the demand response seems to be frontloaded, with a sharper increase during the first six months of the VAT cut. This evidence is in keeping with the counterfactual analysis displayed in Fig. 3, suggesting that consumers were informed of the price cut and responded rationally to the economic incentive by increasing demand quickly. As shown in Ito et al. (2018), residential electricity demand can rapidly respond to economic incentives using each electric appliance (including air conditioners) in a more or less energy-efficient way.

Subsequently, there is no significant change in electricity demand from October 2014 to February 2015, while the demand increases again in the successive months. Interestingly, Fig. 4 highlights the strong correlation between the hours of sunlight and the demand response to the VAT cut. Most of the demand increase occurs during months that are sunnier (and warmer). This suggests that the price elasticity of electricity demand is seasonal. It is higher in sunnier months, which are those with lower energy use. At the same time, it is lower in colder months, those with high energy use.[45] A possible way to understand this finding is that electricity is essential in darker and colder months. Therefore, the price elasticity of demand in those months is very low, as consumers are in high need of electricity regardless of its price. During sunnier and warmer periods, however, the use of electricity is not as essential. Hence, consumers may be more sensitive to variations in the electricity price.

6. Conclusions

This work studies the impact of a VAT cut on the Belgian electricity market, which occurred between April 2014 and September 2015. We study how such a VAT cut affected both the price and demand for electricity. The tax incidence analysis on the electricity market is often made difficult due to the complex tariff structure with non-linear prices depending on the consumption level. In our case, given the (linear) two-part tariff for electricity price (fixed fee and a flat rate), the marginal rate is independent of consumption and equal to the average rate. The VAT is charged equally on the fixed fee and the

[45] This seasonality of price elasticity should not be confused with our result that demand reaction to temperature or sunlight does not depend on the VAT rate. Consumers will always reduce/increase electricity consumption to the same proportion when temperature increases/decreases by 1 degree. This is different from the fact that the effect of VAT (and thus prices) on consumption can change between the summer and the winter.

Table A1
Impact of VAT reform on electricity price components.

Variable	Energy	Green Quota
Intercept	1.59***	−0.08
(β_0)	(0.06)	(0.16)
Household Tariff	0.13***	0.19***
(β_1)	(0.03)	(0.06)
$\mathbf{VAT_{cut}}$	0.09***	−0.08
(β_2)	(0.03)	(0.07)
$\mathbf{VAT_{pass-through}}$	0.99***	1.05
(β_3)	(0.23)	(0.71)
R^2	0.08	0.02
Observations	384	1152

Notes: *, **, and *** indicate statistical significance at the 0.10, 0.05, and 0.01 level, respectively Heteroskedasticity-Robust standard errors are in parenthesis. The price of the energy component varies across contract and client types, but it is homogeneous across network operators. Each of the four contracts has both the firm and household versions, so we have eight different energy price observations for each month over 48 months (384 observations). The price for the green quota can vary across regions, as each of the 3 Belgian regions has different renewable energy quotas requirements. So, we have 24 different green quota prices every month over 48 months (1152 observations).

flat rate. There is no possible confusion on the price, with the consumers mistakenly interpreting the average price as the marginal price. Our VAT incidence analysis in the electricity market involves tax salience, both in terms of simple electricity prices and sizeable tax changes.

We estimate the VAT pass-through to electricity prices by means of a difference-in-differences method, which uses the electricity price paid by firms (not subject to VAT) as a control group. The results show that the VAT cut was entirely shifted to electricity prices and that the pass-through of the VAT cut at 6% and the subsequent reinstatement at 21% was symmetric. This finding contrasts with the previous literature studying VAT incidence in the EU on different markets, which typically finds under-shifting of VAT reductions and asymmetric pass-through between VAT cuts and hikes. Various factors could explain the perfect shifting of the VAT cut to residential electricity prices. A large part of the electricity price, such as transmission and distribution, is entirely regulated. Hence, the VAT pass-through to these tariffs is set to 100% by the regulator. The residual part of the electricity tariffs is the energy price, which is instead non-regulated and set by electricity suppliers. Tax salience, the competitive structure of the retail electricity market, and price adjustment costs may have pushed electricity suppliers to shift the VAT changes entirely to consumers.

We then exploit the (plausibly) exogenous VAT rate changes to estimate the household demand elasticity. Given that the professional electricity demand does not follow the same patterns as the residential demand, we cannot use a difference-in-differences method for our demand analysis. Therefore, we estimate the counterfactual demand under the scenario of no VAT changes conditional on observed covariates, such as sunlight, temperature, solar production, and monthly-distributor fixed effects. This allows us to identify the impact of the VAT cut by computing the difference between the actual and the counterfactual demand for electricity. We back up this analysis with an event study regression exploiting the two instances of VAT change. We also performed robustness checks of our demand analysis, showing that it passed various placebo tests and that the counterfactual demand approach was robust to changes in both estimation and prediction periods.

We find that the VAT cut increased electricity demand by around 2%. Depending on the price variation exploited, we estimate a price elasticity of electricity demand in the range of −0.09 and −0.17, which is in keeping with other recent studies using quasi-experimental variation in electricity prices. Also, our results suggest that the household demand is slightly more reactive to VAT than other price components. A possible interpretation is the greater salience of the VAT change in our context compared to changes in other price components (which are only verifiable a posteriori in the electricity bill). Obviously, this result needs further confirmation given the absence of a proper control group in our demand analysis.

Furthermore, we find evidence of symmetric demand response to the VAT cut and subsequent VAT hike. Consumers were equally sensitive to the price cut and the price hike of a similar magnitude. We also show that consumers reacted immediately to the VAT cut, increasing their demand the next month. This can be a potentially important finding for price-based climate policies, as it would suggest that a simple (linear) tariff structure could stimulate a (more) rational response of households to electricity price changes. However, also this finding needs further confirmation, possibly using a proper control group to study the demand response to electricity prices.

Appendix A. additional figures and tables

Fig. A1 and Table A1

Appendix B. event study regression on the impact of the VAT reform on electricity consumption

To confirm our results about the impact of the VAT reform on electricity consumption, we also run an event study regression. The scope of this method is to identify the "abnormal" electricity consumption during the VAT cut by estimating a model of expected consumption unconditional on the VAT change but conditional on all the relevant information during the sample period. The unexpected change in consumption can then be associated with the VAT change event. Contrary to the counterfactual analysis outlined in regression (3), this model is estimated throughout the period January 2013 - December 2016. This means that observations during months with the 6% VAT rate are also exploited to estimate the determinants of electricity demand.

Both the counterfactual and event study approach estimate similar single-difference models with the same explanatory variables. Their main difference is in the estimation period considered. The first method uses only observations in periods with the 21% VAT rate to predict demand, while the second method exploits all observations (including during the 6% VAT period). If these two methods deliver different results, then either: i) our models fail to explain electricity consumption patterns correctly, or ii) the VAT cut changed how explanatory variables affect demand (e.g., how consumers respond to a rise in sunlight or an increase in temperature). In contrast, if both methods produce similar results, we may explain demand properly since we find the same consumption patterns using different estimation periods. Moreover, this also suggests that the VAT cut did not affect the determinants of electricity consumption but rather produced an orthogonal shift in demand.

The estimation strategy consists of measuring the deviation (from prediction unconditional on the event) in electricity demand during the two VAT change events while controlling for changes in other determinants of electricity consumption. The VAT decreased from 21% to 6% in April 2014 and was reinstated at 21% in September 2015. The aim is to estimate the percentage change in electricity demand following these two events. We do that by estimating the following model:

$$LN(C)_{jt} = \gamma_{jt} + \beta_C VAT_{t>cut} + \beta_H VAT_{t>hike} + \sum_n \theta_n X_{njt} + \varepsilon_{jt}. \tag{6}$$

where $LN(C)_{jt}$ is the natural log of the (average) electricity consumption (measured in kWh per capita) in the area supplied by distributor j during month t. γ_{jt} are the distributor-monthly fixed effects. The variable $VAT_{t>cut}$ is a dummy variable equal to 1 if the monthly observation is during or after the first VAT change in April 2014. Its coefficient β_C approximates the percentage change in electricity demand after the VAT cut, which is equal to $e^{\beta_C} - 1$. The variable $VAT_{t>hike}$ is a dummy variable

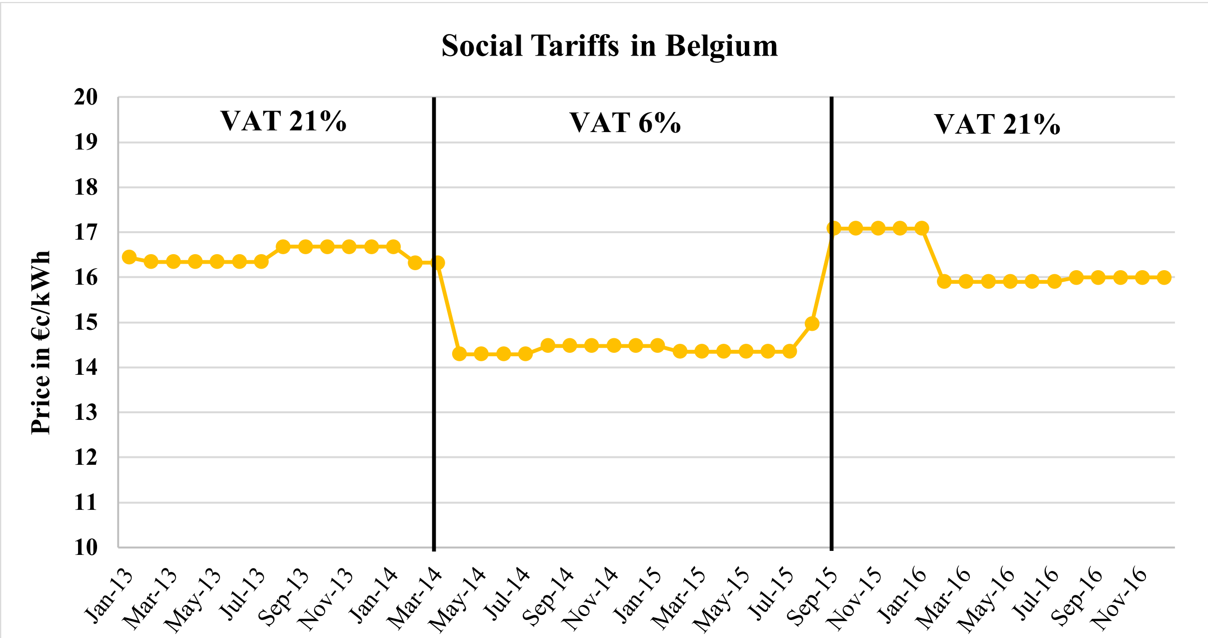

Fig. A1. Social tariffs in Belgium.
Notes: *the series represents the evolution of social tariffs, which are homogenous across Belgium.*

equal to 1 if the monthly observation is during or after the VAT hike in September 2015. Its coefficient β_H approximates the percentage change in electricity demand after the VAT hike, which is equal to $e^{\beta_H} - 1$.

The baseline period is the pre-treatment period (January 2013-March 2014). Hence, if the two effects cancel out (i.e., symmetric response), we would observe that $\beta_C + \beta_H = 0$. Lastly, X_n is the set of covariates used in the (counterfactual) demand model (3). These variables include the amount of electricity auto produced by households, the degree-days (*Degrés-jours Synergrid*), and the hours of sunlight during each month. We also include the electricity price before VAT to control for non-VAT price changes. The price considered is the average across service providers for a given distribution area. We run this regression for both standard and social tariffs.

The results of the regression are shown in Table B1 below. Regression (6) measures the change in demand relative to the baseline pre-treatment demand (January 2013 – March 2014). Columns 1 & 2 (and 5 & 6 for social tariffs) of Table B1 show the result of a different specification using as baseline period both the pre-VAT cut period (January 2013 – March 2014) and the post-VAT hike period (September 2015 – December 2016).

From column 1 to column 4 of Table B1, we show the estimated coefficients for households subject to standard tariffs, which account for most of the electricity consumption. Results are consistent with the counterfactual analysis. The first two columns show that electricity demand was around 2% higher during the VAT cut (taking into account monthly seasonal controls). Columns 3 and 4 display a similar result by separating the demand response to the VAT cut and the subsequent VAT hike. The demand response to the two VAT change events looks quite symmetric. Households first increased their demand by 2% during the VAT cut and then decreased their demand to the same extent once the VAT cut was repealed. This suggests asymmetric demand response to a (significant) VAT decrease and increase of the same size.

Columns 5 to 8 of Table B1 display the estimated coefficients for households subject to social tariffs. They account for a minority of the electricity demand, which is composed of low-income households mostly. Their demand response is similar to other households, with a change in electricity demand close to 2%. The last two columns of Table B1 also show that demand increased by more than 2% during the VAT cut, while it dropped by less than 2% after the VAT reinstatement. This asymmetry, however, can be due to the reduction in social tariffs that occurred after January 2016, which was set by the energy authority partly to protect the low-income group from the VAT reinstatement.[46] Including the price before VAT as a control variable does not account for this effect (its coefficient is even positive).[47]

The coefficients for the control variables have all the expected signs. Interestingly, they are also very similar to those estimated in the counterfactual analysis. This indicates that extending the estimation period for electricity consumption does not affect our estimates of electricity demand. Moreover, this also suggests that the VAT cut has shifted demand upwards without influencing how residential demand reacts to other covariates (like weather fluctuations and auto production).

Appendix C. robustness checks

In this appendix, we run various robustness checks to validate our results. We focus primarily on validating our consumption analysis as it does not rely on a proper control group, contrary to the VAT pass-through estimation. Our first round of checks focuses on validating the counterfactual model by running the following tests. We estimate the demand variation when we either: i) enlarge the estimation period to the year 2012 ;[48] or ii) enlarge the prediction period to two years (2014 - 2015). We find a very similar (although slightly higher) demand variation during the VAT cut period in both cases. These results are shown in the first two rows of Table C1 below.

Table C1 also shows the results of two placebo tests. In the first placebo test, we estimate the model by excluding the VAT cut period and predict the consumption during the period 03/2012 – 09/2013, which is the same time interval of the VAT cut but in the year before the treatment. We then compute the difference between actual and predicted demand for this period and find it very close to zero. This suggests that the deviation from prediction occurred during the VAT cut period only.

Since the demand response was concentrated during summer, we also ran a placebo test for the summer of 2016, which is the first post-treatment summer (after the VAT cut was repealed). We estimate the demand by excluding from the sample the summer 2016 and the summers 2014–2015 with reduced VAT. We then predict consumption for these periods and compute the difference in demand. We find that the difference between actual and predicted consumption is around 4.4% during the summers of 2014 and 2015. In contrast, it is close to zero (0.12%) during summer 2016. This suggests that the "abnormal" demand occurred only during the summers of VAT cut and that consumption reverted to the predicted level after the VAT was reinstated at 21%.

We also run an additional placebo test, based on the event study regression, tracking business consumption during the period of VAT changes. Business demand is not subject to VAT, and so it should not be affected by the reform. The test consists of checking whether we observe a parallel change of electricity demand for firms and households, suggesting that

[46] A Figure showing the evolution of Social tariffs can be found in Appendix A.

[47] Social tariffs are fully regulated and the only two sources of variation over the sample period are the VAT change (mainly) and the update in January 2016. Thus, the positive coefficient for the price net of VAT should not be indicative, as it could be due to the little variation in the price data and its correlation with some unobserved factor after January 2016.

[48] We include data about electricity consumption during the year 2012 in the robustness analysis only. We do not include them in the main analysis as we do not have price data for that period. Hence, we do not control for differences in price level as we do in the event study regression.

Table B1
Impact of VAT reform on demand.

	Standard Tariffs (1–4)				Social Tariffs (5–8)			
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VAT cut	2.12	2.05	2.06	2.07	1.99	1.81	2.59	2.48
($\boldsymbol{\beta_C}$)	(0.20)	(0.20)	(0.41)	(0.40)	(0.22)	(0.23)	(0.49)	(0.49)
VAT hike			−2.14	−2.05			−2.08	−1.60
($\boldsymbol{\beta_H}$)			(0.23)	(0.24)			(0.27)	(0.28)
Degrees-Days	0.56	0.57	0.56	0.57	0.56	0.59	0.54	0.58
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Sunlight	−0.49	−0.48	−0.49	−0.48	−0.47	−0.44	−0.44	−0.44
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)
Auto production	−1.59	−1.50	−1.57	−1.51	−0.77	−0.72	−0.98	−0.93
	(0.05)	(0.07)	(0.12)	(0.12)	(0.07)	(0.07)	(0.16)	(0.16)
Price		−0.04		−0.04		0.34		0.35
(no VAT)		(0.02)		(0.02)		(0.05)		(0.05)
Observations	720	720	720	720	720	720	720	720

Notes: Heteroskedasticity-Robust standard errors are in parenthesis. All coefficients are statistically significant at the 0.01 level, except the one on price (net of VAT) in columns 2 and 4. All models include distributor-monthly FEs. Their R-squared is around 99%. Without including such interactions, results are very similar, but the R-squared drops to 97%. The coefficients for the VAT cut and VAT hike (and their respective standard errors) are rescaled (multiplied by 100) to display the results better.

Table C1
Robustness checks for counterfactual analysis.

Test	Estimation Period	Out-of-SamplePrediction Period	% difference(VAT 6% period)
Extended estimation period	01/2012 – 02/2014 10/2015 – 12/2016	03/2014 – 09/2015	2.78 [2.33 - 3.15]
Extended prediction period	01/2013 – 12/2013 01/2016 – 12/2016	01/2014 – 12/2015	2.70 [2.30 - 3.10]
Placebo-previous years	10/2013 – 03/2014 09/2015 – 12/2016	03/2012 – 09/2013	−0.13 [−0.57 – 0.31]
Placebo-summer 2016	01/2012 – 12/2016 Excl. summers '14, '15, '16	Summers '14, '15 Summer '16	4.44 [3.79 – 5.10] 0.12 [−0.66 – 0.89]

Notes: The last column shows the% difference between the actual and predicted consumption in the out-of-sample period during months with the reduced VAT rate only. Months that are out-of-sample with VAT rate at 21% are not considered in such difference. In the placebo tests, the difference is computed with respect to the out-of-sample period displayed. Values in parenthesis are the 95% confidence interval of this difference.

Table C2
Placebo test: impact of VAT reforms on business consumption.

Variable	Business(1)	Business(2)	Households(3)	Households(4)
VAT_{cut}	−0.28	−0.19	2.07***	2.01***
	(1.33)	(1.11)	(0.40)	(0.42)
VAT_{hike}	−5.30***	−1.27	−2.05***	1.33***
	(0.60)	(1.05)	(0.24)	(0.15)
Auto production	−0.11***	−0.07***	0.57***	−0.18***
	(0.02)	(0.01)	(0.02)	(0.01)
Degree-Days	0.04***	0.05***	−0.48***	0.07***
	(0.00)	(0.00)	(0.03)	(0.00)
Sunlight	−0.07***	−0.06***	−1.51***	−0.04***
	(0.01)	(0.00)	(0.12)	(0.00)
Price	0.04	0.07**	−0.04**	−0.02
(net VAT)	(0.03)	(0.03)	(0.02)	(0.02)
Time Trend	no	yes	no	yes
R-squared	0.98	0.99	0.99	0.99

Notes: *, ** and *** indicate statistical significance at the 0.10, 0.05 and 0.01 level, respectively. Heteroskedasticity-Robust standard errors are in parenthesis. Control variables also include distributor FE, monthly FE, and their interaction. The coefficients for the VAT cut and VAT hike (and their respective standard errors) are rescaled (multiplied by 100) to display results better.

non-VAT factors can drive our results. To do so, we estimate regression (6) in Appendix B for both household and business consumers. The results of this test are shown in Table C2 below.

Column 1 of Table C2 shows the results of this business placebo test. The coefficient for the VAT cut is not significant and close to zero, indicating no significant changes in business demand conditional on the VAT cut event. However, the same demand from households increased by 2% (see column 3). Since only households are subject to the VAT, this evidence suggests that the residential demand increase can be associated with the VAT cut event. Considering the subsequent VAT hike event, we find a coefficient for business demand that is negative and significant. This indicates that the business consumption conditional on the VAT hike event is significantly smaller than the unconditional demand. This effect is probably due to non-VAT factors influencing the business demand. Indeed, once we control for a linear time trend, the VAT hike effect disappears (as indicated in column 2), suggesting a declining time trend of the business demand after the VAT hike.

We also report the estimates for household consumers after controlling for the time trend in electricity consumption. Interestingly, we find that our estimate for the VAT cut remains unchanged at 2%. Even accounting for a time trend in electricity demand, we still observe a positive increase in demand by 2% after the VAT cut. However, the inclusion of the time trend makes it difficult to correctly identify the effect of the VAT hike treatment because it is highly correlated with the time trend. In Table C2, the household demand coefficient for the VAT hike is positive instead of being equal to −2% (without the time trend). Nevertheless, we believe that the symmetric demand response is more likely for two reasons. First, the time trend is not affecting the VAT cut effect on household demand (+2%), suggesting that there is no pre-treatment trend affecting our findings. Second, since the VAT hike dummy is highly correlated with the time trend, there is a risk that the decrease in residential demand following the VAT hike is spuriously confounded with a negative time trend in consumption.

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