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The Effects of a Large Energy Price Shock on Firm Credit

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This study investigates how credit to firms responded to the energy price shock triggered by the Russian invasion of Ukraine. Credit growth of energy-intensive firms declined by 8.75 percentage points relative to comparable non-energy-intensive firms. Less risky firms reduced credit demand, whereas banks reduced supply of new loans to riskier firms.

Keywords

Credit register

Climate

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The Effects of a Large Energy Price Shock on Firm Credit*

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Abstract

This study investigates how credit to firms responds to an energy price shock by comparing the credit growth of similar firms with different energy intensities before and after the shock triggered by the Russian invasion of Ukraine. Credit growth of energy-intensive firms declined by 8.75 percentage points. A large part of this decline stems from less risky firms drawing less on preexisting credit lines. Interest rate spreads for new loans rose for riskier firms. The results suggest that less risky firms reduced credit demand, whereas banks reduced supply of new loans to riskier firms.

Keywords: energy price shock, firm credit, credit register, firm heterogeneity

JEL Classification: G21, G32, Q43

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1 Introduction

What are the effects of large energy price shocks on the economy? Since the 1970s, an extensive literature has studied this question, mainly focusing on the effects of oil price shocks. More recently, the large energy price increase in the wake of the Russian invasion of Ukraine has put shocks to other energy prices, like those of gas or electricity, into the spotlight. Concerns that energy prices will fluctuate more in the future because of geopolitical events and the green transition have motivated a recent literature that tries to identify the impact of such shocks. However, it is difficult to isolate the effect of energy price shocks using aggregate data alone, as such shocks often coincide with other events, introducing confounding factors. For example, the Russian invasion of Ukraine increased geopolitical risk, affecting credit demand and supply. Because of sanctions, supply chains ruptured, reducing economic activity and depressing credit demand. As a result, how to isolate the impact of energy price shocks on the economy remains an open question.

This paper uses Danish microdata to provide novel empirical evidence on the impact of energy price shocks on bank credit to firms, using the energy price shock triggered by the Russian invasion of Ukraine as a case study. For many firms, bank loans are important for financing investments and operations. Understanding the impact of such shocks on credit is therefore important for understanding its impact on many other firm decisions and, eventually, on the overall economy. Moreover, firm loans make up a significant fraction of many banks' assets, so understanding the credit impact is also important for understanding the impact on financial institutions.

Using a difference-in-differences approach, we find that the credit growth of high-energy-intensity firms declined temporarily by 8.75 percentage points relative to low-energy-intensity firms. As the energy intensity of energy-intensive firms increased by 0.72 percentage points relative to low-energy-intensity firms, this translates into a 12.15 percentage point fall in credit growth per percentage point increase in energy intensity. This effect is large: for comparison, over the entire sample period from the third quarter of 2019 to the fourth quarter of 2023, aggregate credit to the manufacturing sector increased by a peak of 22.02 percentage points in the fourth quarter of 2022 before declining again, increasing cumulatively by only 4.85 percentage points in the fourth quarter of 2023.

We then present evidence suggesting that a reduction in credit demand played an important role in this decline in credit growth. We argue that this decline in credit demand occurs for precautionary reasons, as less risky firms wanted to increase their distance to their borrowing constraints to avoid becoming financially constrained in the future, consistent with the theoretical models of Bolton, Chen, and Wang (2011) and Eisfeldt and Muir (2016). Firstly, most of the decline is due to a relative reduction in high-energy-intensity firms' utilization of their preexisting credit lines, which are an important source of liquidity (Ivashina and Scharfstein 2010; Greenwald, Krainer, and Paul 2025; Chodorow-Reich, Darmouni, Luck, and Plosser 2022).[1] Secondly, the decline in credit growth is more pronounced for more liquid and less risky firms, and firms with a higher share of debt maturing right after the shock.[2] We also find that energy-intensive firms that borrowed after the shock faced higher interest rates, even when we control for loan type composition and borrower risk. This tightening of credit conditions is more pronounced for firms with higher ex-ante probabilities of default. So, while a decline in credit demand seems to explain the large drop in credit growth in the second quarter of 2022, the supply of new loans to the more risky energy-intensive firms was tightened.

Our results have important implications for researchers and policymakers interested in understanding the economic and financial impact of energy price shocks, and shocks to firms' production costs (cost-push shocks) more generally. While one would expect that such shocks increase energy intensive firms' risk, reducing the credit supply to exposed firms, it is not clear whether credit demand would increase or decrease. We show that differences in financial health are a crucial determinant of the response of firms to such shocks, with financially unconstrained firms reducing credit demand and financially constrained firms being more exposed to the reduction in credit supply. Therefore, researchers should account for the distribution of financial constraints in analyzing the effects of such shocks. Second, we demonstrate how to use granular data on different types of credit to isolate the effects of the energy price shock on credit supply and credit demand.

1.1 Overview of the Paper

Section 2 introduces the dataset. The key data source is a survey about the energy consumption of Danish manufacturing establishments. It contains detailed information on the energy consumption of all manufacturing establishments in Denmark with more than 20 employees, measured in quantities and values. We combine this dataset with the Danish credit register, which contains quarterly bank-reported information on all bank loans in Denmark. We obtain a unique dataset that allows us to trace out the impact of the shock at business cycle frequencies, which is unusual for administrative data. Our dataset contains firm identifiers, so we can merge it with additional firm-level data, giving us a rich set of additional firm characteristics such as firm size and -age and balance sheet information.

1. Greenwald et al. (2025) and Chodorow-Reich et al. (2022) document an *increase* in credit line drawdowns following the onset of Covid-19, driven by larger firms. This different behavior suggests that Danish firms did not expect a broad disruption of bank credit during the energy crisis, in contrast to US firms during Covid-19.

2. The decline in credit demand could also be because of a wait-and-see channel (Bernanke 1983; Bloom 2009; Alfaro, Bloom, and Lin 2023), whereby firms reduced investment and credit demand because of higher uncertainty.

Section 3 discusses the energy price shock, its impact on the Danish economy and how we identify its causal effect on firm credit. The energy price shock following the Russian invasion of Ukraine is of considerable interest for two reasons. First, it was largely unforeseen. Before the 24th of February, when the invasion started, many observers believed that Russia was unlikely to invade Ukraine. Second, it was large. As we observe both quantities and values of energy consumption, we can compute firm-level energy prices by dividing the value of energy consumption by the quantity of energy consumption. In our data, energy prices rose by around 70 per cent from 263 DKK ($\approx$ 35 EUR) to 448 DKK ($\approx$ 60 EUR) per Gigajoule. The increase in effective energy prices was similar for high and low-energy-intensity firms. High-energy-intensity firms were, however, more exposed to the energy price shock. The price increase led to an increase in energy expenditure as a share of revenue of 2.19 percentage points for the average high-energy-intensity firm, as opposed to 0.26 percentage points for the average low-energy-intensity firm.

We use a difference-in-differences approach to isolate the effect of the energy price shock on credit. The idea is to compare the credit growth of firms that differ in energy intensity but are otherwise similar before and after the energy price shock. We control for granular industry-time and bank-time fixed effects to compare high-energy-intensity and low-energy-intensity firms. Assuming that other factors, such as increased geopolitical risk, similarly affected the credit of firms with different energy intensities within the same industry and bank, we can interpret the differences in credit growth between low- and high-energy-intensity firms following the energy price shock as a causal effect.

Section 4 contains the estimation results. The first main result is that credit growth fell due to the energy price shock. In particular, we find that the credit growth of high-energy-intensity firms relative to low-energy-intensity firms fell by 8.75 percentage points in the second quarter of 2022. Credit growth did not rise until the third quarter of 2023. This fall in credit growth implies that the level of credit of high-energy-intensity firms declined persistently relative to that of low-energy-intensity firms. This effect is economically meaningful. A relative increase in energy expenditure of 1.93 percentage points led to a fall in credit growth of 8.75 percentage points. This effect, in terms of size and statistical significance, is robust to different definitions of energy intensity and many robustness checks. For example, using a more granular definition, we find that the effect is more pronounced for firms with higher energy intensity, suggesting that it is indeed due to the energy price shock.

The main challenge in identifying the causal credit growth effect is the potential for another characteristic correlated with energy intensity to affect credit growth dynamics during the energy price shock. In such a case, the parallel trend assumption would be violated, and the estimated effect would be biased. For example, smaller firms are more energy-intensive and might, at the same time, be more affected by sanctions. However, in regressions where we also control for differential dynamics in other firm characteristics, we show that the effect of the energy price shock is not due to differences in firm size, age, leverage or riskiness, suggesting that it is most likely differences in the exposure to the energy price shock that drive the estimated effect.

In section 5, we conduct two additional analyses to investigate whether the fall in credit growth is due to a decline in credit supply or credit demand. First, we decompose the decline in credit growth into contributions coming from different types of credit, finding that three-quarters of the decline stems from credit lines, with the rest coming from credit cards. Additional decompositions suggest that the decline in credit growth is due to a reduction in preexisting credit lines. We show that this reduction is not a result of credit institutions lowering (binding) credit limits but rather of firms utilizing preexisting credit lines less. Second, we investigate the extent of heterogeneity in the effect of the energy price shock on credit growth across firms. Our data enables us to study heterogeneity among many dimensions, like firm size, firm age, liquidity, riskiness, or the share of debt due in the quarter of the shock. We find that the decline in credit growth because of the energy price shock is more pronounced for firms with a high share of debt due in the quarter of the shock, ex-ante smaller, older, less risky firms and firms with higher cash balances. Those are all firms that one would expect to be less credit-constrained.

Section 6 analyzes the effects of the shock on loan terms of new loans (i.e. loans issued in the current quarter) further to investigate the role of credit supply vs. credit demand. At the firm level, we find some, but not strong, evidence of a tightening of loan terms for new loans: interest rates on new loans of high-energy-intensity firms rose by about 1 percentage point relative to those of low-energy-intensity firms, maturities declined, and collateral requirements rose.[3] As these results can be blurred due to possible shifts in the composition of instrument types and borrower risk, we move to loan-level regressions, allowing us to control these two features. The interest rate spread on new loans rose but only for younger, larger and more risky firms. Those are all firms that one would expect to be more credit-constrained.

1.2 Literature

This paper contributes to the literature on the effects of energy price shocks on the financial decisions of firms and banks. The closest paper to this one is Ivanov, Kruttli, and Watugala (2024), which analyzes the effect of the Californian cap and trade policy for CO2 emissions on credit supply, finding a negative effect. We analyze a different type of shock and are, in addition, able to distinguish between credit demand and credit supply

3. The increase in interest rate could potentially be solely due to an increase in the demand for new loans. However, we would most likely observe an increase in the growth of new loans, which we do not.

channels, showing that the former are important for the overall effects of the shock.

Our results are further related to the literature that studies the effects of shocks to energy prices on macroeconomic outcomes. The closest paper is Davis and Haltiwanger (2001), which studies the establishment-level effects of oil price shocks. They find that oil price shocks are important for employment, especially for capital-intensive, energy-intensive and durables-producing firms. They do not consider the effects of the shocks on firm credit.

Many other papers analysing the effects of energy price shocks use time series identification approaches, complementing this paper's difference-in-differences approach. For example, Kilian (2009) decomposes oil price movements into shocks to oil supply, global aggregate demand, and precautionary oil demand, arguing that demand shocks primarily drive oil prices. Baumeister and Hamilton (2019) revisit the same question, arguing that Bayesian models that generalize existing identification approaches imply larger importance of oil supply shocks in driving oil prices. Känzig (2021) identifies oil supply news shocks from OPEC announcements, arguing that they negatively affect the US economy. Alessandri and Gazzani (2023) identify gas supply shocks using a high-frequency approach and argue that they have persistent stagflationary effects. Boeck and Zörner (2025) and Adolfsen, Ferrari Minesso, Mork, and Van Robays (2024) investigate the impact of natural gas price shocks on inflation and inflation expectations.

Finally, the results of this paper are related to the literature that investigates the heterogeneous impact of aggregate shocks on different firms. Gertler and Gilchrist (1994), Begenau and Salomao (2019), Crouzet and Mehrotra (2020) and Clymo and Rozsypal (2022) study differences in the unconditional cyclicality of firms. A growing literature studies the conditional effects of aggregate shocks, in particular monetary policy shocks to different firms (Ottonello and Winberry 2020; Jeenas 2019; Cloyne, Ferreira, Froemel, and Surico 2023; Palazzo and Yamarthy 2022; Jungherr, Meier, Reinelt, and Schott 2022) or financial shocks (Chodorow-Reich 2014). To our knowledge, no paper studies the effects of energy price shocks on different firms.

2 Data

This section describes the datasets, discusses how we construct key variables and explains our sample selection procedure. Appendix A provides summary statistics.

2.1 Data Sources

The main analysis uses two primary datasets. The first is a biannual survey of manufacturing establishments' energy use. The second is a credit register containing information on all bank loans. We also merge these data with rich administrative data on firm balance sheets.

2.1.1 Energy Use

The data on energy use come from a biannual survey conducted by Statistics Denmark.[4] All establishments of firms with more than 20 employees in the manufacturing sector are legally required to report. The dataset covers around 90 per cent of the energy consumption of the manufacturing sector. Appendix A reports how this sample compares to the population of all Danish firms. It contains information on annual energy consumption at the establishment level by type of energy and usage.

Regarding the type of energy, there are 18 categories, e.g. coal, electricity, or natural gas. There are three categories of energy usage: heating, common industrial processes, and special industrial processes.[5] All categories are reported in values and quantities, which enables us to construct prices by dividing values by quantities.

The data is available every other year from 2012 to 2022.[6] We aggregate data at the firm level by summing up energy consumption in a given year within a firm across establishments.

2.1.2 Credit Register

The credit register contains information on all individual loans from Danish banks. It is a quarterly dataset, starting in the first quarter of 2019. We use it until the fourth quarter of 2023. Small banks only report annually but only make up about five per cent of total loans. We focus, therefore, on medium-sized and large banks. The credit register contains information on outstanding amounts at the end of the quarter, interest rates, loan maturities, loan origination dates, and loan delinquencies.

We clean the data as follows: For maturities, we replace all negative maturities and maturities above 50 years with missing values.[7] For interest rates, we replace all interest rates below -1 per cent and above 50 per cent with missing values. We define *new loans*

4. It is documented here: Statistics Denmark (2024).

5. Special processes refer to mineralogical and metallurgical processes, including electrolysis and chemical reduction. Common processes refer to all processes besides special processes and heating.

6. In principle, the data go back to 1995. However, coverage increased in 2012, so the data from 2012 onward is not readily comparable to earlier data.

7. We treat credit lines as having zero maturity.

as loans originating in the current quarter.

We aggregate the data at the bank $\times$ firm $\times$ quarter level to obtain a quarterly panel dataset, i.e., we sum outstanding debt within each quarter for each bank-firm pair. We compute credit growth as

$$credit\_growth_{fbt} = 100 \times \frac{C_{fbt} - C_{fbt-1}}{0.5\,(C_{fbt} + C_{fbt-1})}, \tag{2.1}$$

where C_{fbt} is outstanding debt of firm f at the end of quarter t at bank b. This measure has the advantage of allowing for changes in credit at intensive and extensive margins. Having only lagged credit growth in the denominator would create problems if lagged credit is zero. This is a relevant issue because there are many zeros in the data at the bank $\times$ firm $\times$ quarter-level.

2.1.3 Firm Balance Sheets

We merge the dataset with firm balance sheet data, which has been available annually since 2001. These data contain information on the universe of Danish firms. We obtain the following variables: starting date, employment, revenue, imports, exports, total debt, short-term debt, current assets, inventories, and capital.

2.2 Measuring Energy Intensity

The main measure of energy intensity measures expenditure as a share of firm revenue.[8] We calculate the revenue-based energy intensity of firm f in year t as

$$EI_{ft} = 100 \times \frac{energy\_dkk_{ft}}{revenue_{ft}}. \tag{2.2}$$

$energy\_dkk_{ft}$ is the energy consumption of firm f in year t, measured in thousands of DKK. $revenue_{ft}$ is the revenue of firm f in year t, likewise measured in thousands of DKK. EI_{ft} is the energy expenditure share in firms' revenue. This definition of energy intensity is common in the literature (Meng 2017; Ivanov et al. 2024). To split firms into low and high-energy-intensity firms, we calculate the average energy intensity of firm f between 2012 and 2020 according to

$$\bar{EI}_f = \frac{1}{5} \sum_{t=2012}^{2020} EI_{ft}. \tag{2.3}$$

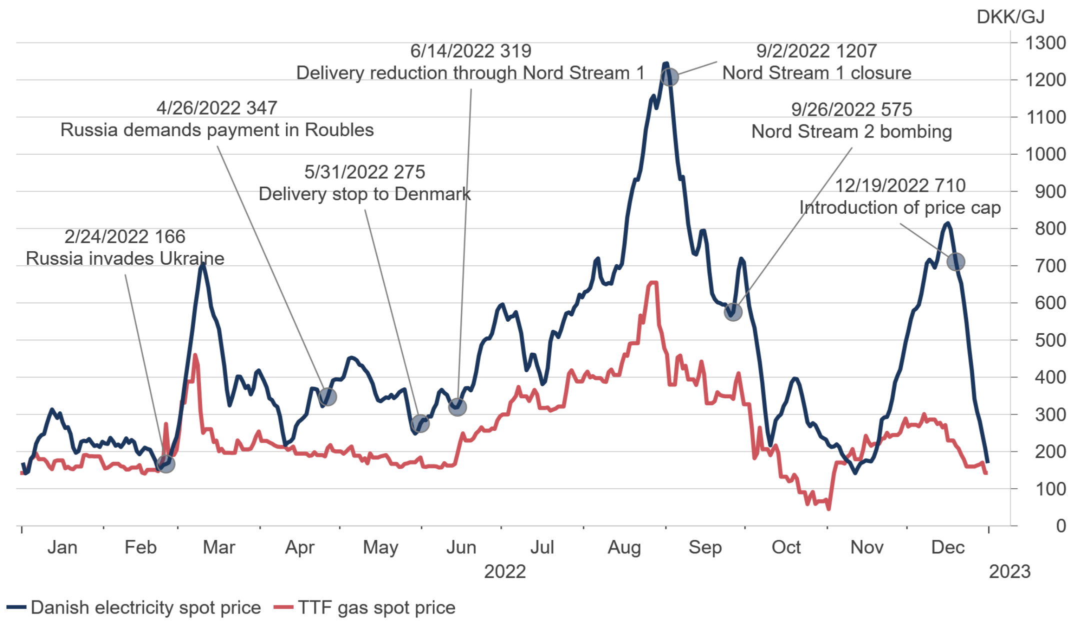
8. If the firm operates in a competitive market, can flexibly adjust inputs and uses a Cobb-Douglas production technology, this measure is the coefficient of energy in the production function.

Note that the energy data are biannual, so we have 5 observations from 2012 to 2020.

3 Empirical Design

This section first describes the energy price shock and how it impacted the energy costs of Danish manufacturing firms. Second, it discusses the identification of the causal effect of the increase in energy prices on credit. Third, it presents the empirical model we use for the main results.

3.1 The Energy Price Shock of 2022



(a) Energy spot market prices and events during 2022

Figure 1: Energy prices

Note: This figure shows the aggregate gas and energy price developments in Denmark. The electricity spot price is the average price at Nordpool, measured as a 14-day moving average. The gas price is the price of TTF natural gas, and the oil price is per barrel of Brent. Prices are based on monthly contracts.

International Developments Figure 1 shows the development of energy prices since the start of 2022. Because gas is the marginal source of electricity generation in Denmark when electricity demand is high relative to electricity supply, electricity prices and gas prices co-move strongly (Branner and Ingholt 2023). In September 2021, energy prices started to rise.[9] At the time, this was attributed to a lower gas supply from Russia, but without suspicions of a looming invasion of Ukraine.[10] By the end of the year, as the

9. See Sheppard and Wilson (2021).
10. See Sheppard (2021).

risk of an invasion of Ukraine by Russia became more material, gas and electricity prices increased in lockstep.

Energy prices increased even more after the invasion in February 2022 and dramatically spiked during Spring 2022 when Russia started to shut off gas supplies to some European countries, including Denmark. During the summer of 2022, the energy price shock was further aggravated by adverse weather conditions, leading to lower electricity production by nuclear and hydroelectric power plants in Europe (Branner and Ingholt 2023). There was another increase in gas and electricity prices in the third quarter of 2022 when it became apparent that Russia wanted to close the Nord Stream 1 pipeline. Since then, while energy prices have fallen, they remain substantially above their levels at the beginning of 2019.

There are different explanations for why energy prices have increased that much.[11] Because we rely on a difference-in-differences approach, the energy price shock source is unimportant as long as it affects firms with different energy intensities differently.

How did this spike in energy prices affect firms? One hypothesis is that the high volatility of gas prices caused substantial uncertainty about the future profitability of energy-intensive firms. They first had to learn whether the shock to energy prices was transitory or permanent. As a result, these firms could have decided to reduce credit demand to increase their distance from their borrowing constraint, in line with the theories of Bolton et al. (2011) and Eisfeldt and Muir (2016) and to postpone investment until the uncertainty was resolved, in line with the theories of Bernanke (1983) and Bloom (2009).Another hypothesis is that banks cut credit to energy-intensive firms because the banks perceived the firms to be more risky. Under the second hypothesis, we would expect that loan terms for energy-intensive firms would also deteriorate.

Importance for Denmark Denmark is an energy-importing country. In 2023, Denmark imported around half of its total energy consumption. European energy markets are well integrated, so Danish energy prices increased similarly to the rest of Europe. Denmark relies, however, relatively little on Russian gas (Di Bella, Flanagan, Foda, Maslova, Pienkowski, Stuermer, and Toscani 2024). The main gas importer from Russia, Ørsted, was shut off from the Russian gas supply in May 2022 after refusing to pay for gas

11. One explanation is that it was because of the reduction in supply. However, besides the price increase following the invasion date, no other events were followed by drastic price movements, suggesting that the direct price impact of these supply events was limited. Another explanation is that it was because of a rise in precautionary energy demand because of higher supply uncertainty. Kilian (2009) and Baumeister and Hamilton (2019) discuss the importance of such precautionary demand shocks in the oil market. According to this explanation, prices for gas and other sources of energy increased as governments raced to stockpile energy for the Winter of 2023. Short-run limitations in expanding supply would then drive prices up. This latter explanation is consistent with the observation that gas storage in Europe grew quickly during these months. Adolfsen et al. (2024) provide econometric evidence that supply and precautionary demand contributed to the gas price increase in 2022.

deliveries in roubles.[12]

Danish Policy Reaction Due to the increase in energy prices, the Danish government introduced a lending scheme where households and firms could postpone up to 50 per cent of their energy bill by up to five years. However, uptake of this scheme was limited both among households and firms.[13] It likely played no significant role in explaining our main result about the effect of the energy price shock on firm credit.

3.2 Effect on the energy intensity of high- vs low-energy-intensive firms

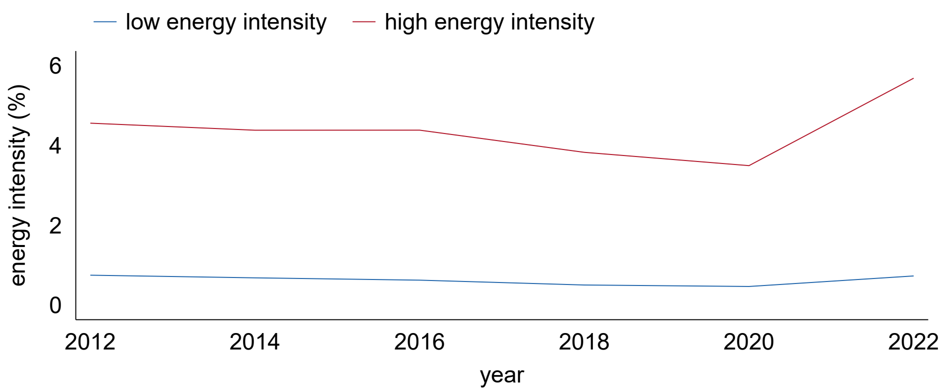


Figure 2: Dynamics of average energy intensity, low-energy-intensity vs high-energy-intensity firms.

Note: This figure shows the average energy intensity, computed as energy consumption divided by revenue, for high-energy-intensive and low-energy-intensive firms. The former are those firms with an energy intensity above median, the latter with an energy intensity below median.

Figure 2 shows our sample's average energy intensities, prices, and consumption for high- and low-energy-intensity firms. Overall, the energy intensity of high-energy-intensity firms increased more than that of low-energy-intensity firms. Panels 9a and 9b of Figure 9 in Appendix A decompose energy intensity into its numerator and its denominator, showing that while the value of energy consumption increased much more for energy-intensive firms, they were also able to pass through a large part, though not all, of this increase by raising revenues.

Panels 9c and 9d of Figure 9 in Appendix A show that the increase in the value of energy consumption is not driven by prices, which increased similarly for both groups of firms.[14]

12. Ørsted (2022)
13. Bang-Udesen (2022)
14. Average prices are higher than the aggregate price in Figure 1, suggesting that firms that consume a large amount of energy pay lower prices.

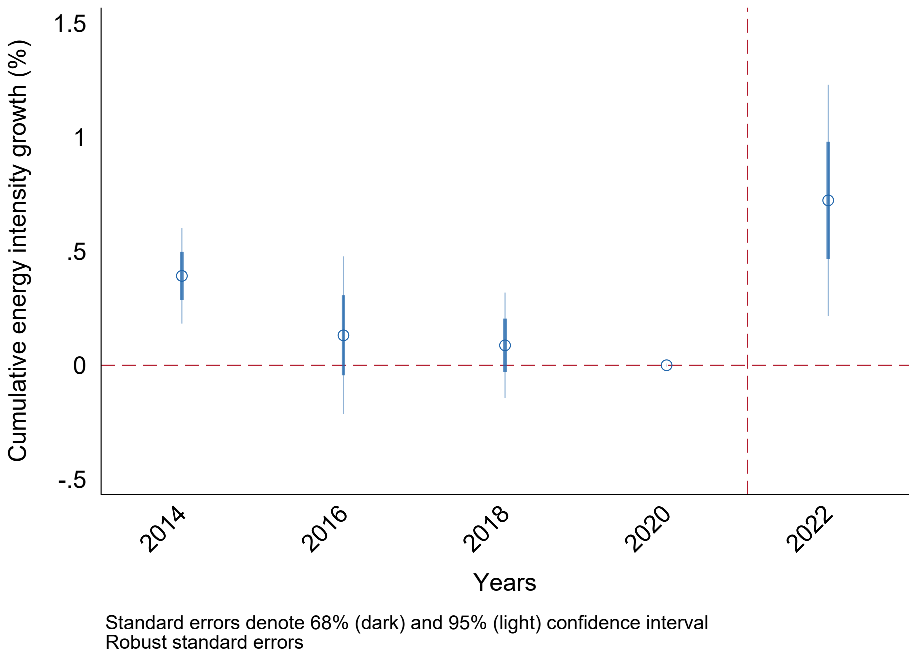


Figure 3: The effect of the energy price shock on energy-intensive firms' energy intensity.

Note: This figure shows the coefficients β^h of estimating regression 3.1. Period: 2014-2022. Source: ENERGI, FIRE, FIRM and own calculations.

Instead, quantities slightly increased for high-energy-intensity firms, while they fell for low-energy-intensity firms. This evidence suggests that high-energy-intensity firms could not substitute away from energy use and that they, because of their higher exposure, were more affected by the energy price shock than low-energy-intensity firms.

To estimate the effect of the energy price shock on high-energy-intensive firms' energy intensity, we estimate the following local projection:

$$EI_{f,\tau+h} - EI_{f,\tau} = \alpha^h + \beta^h 1_{\bar{EI}_f = high} + \sum_{s=1}^{4} \gamma_s^h EI_{f,\tau-s} + \delta^h_{sector_f} + \varepsilon_{f,\tau,\tau+h}. \tag{3.1}$$

$EI_{f,\tau+h}$ is the energy intensity of firm f h periods ahead of the reference period, $EI_{f,\tau}$ the energy intensity in the reference period, in this case 2020. We choose 2020 as it is the last year where we observe energy intensity before the energy price shock in the biannual survey. $1_{\bar{EI}_f=high}$ is a dummy that is equal to one if the energy intensity of firm f is high in the period 2014-2020. We control for as many lags of energy intensity as we can, i.e. for zero lags in 2014, one lag in 2016, and so on. This lag-augmentation ensures that residuals are not autocorrelated (Montiel Olea and Plagborg-Møller 2021). We use heteroskedasticity-robust standard errors.

Figure 3 shows that the energy intensity of energy-intensive firms decreased from 2014 to 2016, likely because of the green transition. This decline then stalled, and energy intensity was relatively stable prior to 2022. It then increased markedly by 0.72 percentage points in 2022. This increase is highly significant. This establishes that the pattern documented in Figure 2 also hold in a regression framework.

3.3 Identifying the Causal Effect of the Energy Price Shock

We are interested in estimating the causal effect of the increase in energy prices on firm credit. The simplest approach would be to compare credit before and after the invasion. However, this approach is not valid, as the increase in energy prices coincided with many additional events caused by the Russian invasion, e.g. an increase in geopolitical risk, supply chain disruptions, and sanctions against firms operating in Russia. Moreover, the Danish economy was still recovering from Covid, which also affected macroeconomic and sectoral trends.[15]

For the same reasons, it is also impossible to infer the effect of the energy price shock by comparing the credit growth of energy-intensive and non-energy-intensive industries. Covid and the Russian invasion affected different industries differently, making non-energy-intensive industries an unsuitable comparison group for energy-intensive industries. In other words, comparing different industries is likely to violate the parallel trends assumption.

We, therefore, turn to firm-level data. By comparing firms with different energy intensities in the same, narrowly defined industry, we alleviate the concern that these firms were differently affected by other macroeconomic shocks besides the energy price shock. We define industries at the most granular level, comprising more than 800 industries.

A second concern is that different lenders could have been affected differentially by the shock. For example, some lenders with higher exposure to Russian loans could have been forced to tighten credit supply more than other banks. The parallel trend assumption would again be violated when comparing the credit growth of firms borrowing from these exposed banks with that of other firms. Therefore, we account for time-varying credit supply conditions by including bank $\times$ time fixed effects (Khwaja and Mian 2008; Degryse, De Jonghe, Jakovljević, Mulier, and Schepens 2019).

By including bank $\times$ time and industry $\times$ time fixed effects, we effectively compare high-energy-intensity firms (treatment group) to low-energy-intensity firms within the same narrow industry borrowing from the same bank (control group). This approach implies a comparable control group, thus making the assumption of parallel trends more plausible.

15. For an alternative approach using aggregate data that relies on constructing a narrative measure of gas supply shocks, see Alessandri and Gazzani (2023).

3.4 Econometric Model

To estimate the causal effect of the energy price shock on credit growth, we therefore estimate the following model:

$$credit\_growth_{fbt} = \alpha + \sum_{\tau=T_1}^{T_2} \beta_\tau \left(1_{\bar{EI}_f=high} \times 1_{t=\tau}\right) + \delta_f + \delta_{sector_f t} + \delta_{bt} + \varepsilon_{fbt} \qquad (3.2)$$

$credit\_growth_{fbt}$ is credit growth of firm f at bank b from time $t-1$ to t, α is a constant, $1_{t=\tau} \times 1_{\bar{EI}_f=high}$ is a set of interacted time and high-energy-intensity dummies. δ_f is a set of firm dummies that control for average differences in credit growth across firms. $\delta_{sector_f t}$ is a set of time × industry dummies that control for industry-specific dynamics, such as sanctions imposed on certain groups of goods or supply shortfalls that hit all producers in a given industry equally. δ_{bt} is a set of time × bank dummies that control for bank-specific dynamics, for example, changes in bank-specific credit supply. ε_{fbt} is a residual. We doubly cluster residuals at the industry and quarter level to allow for autocorrelation for the individual bank-firm observation and within industries (Bertrand, Duflo, and Mullainathan 2004). Clustering at the quarter level also takes account for correlation across bank-firm observations within the same time period.

The coefficients of interest are the β_τs. We set $T_1 = 2021Q2$ and $T_2 = 2023Q4$, which effectively normalizes the coefficients relative to the 2020Q1-2021Q1 period. These coefficients measure the difference in credit growth of energy-intensive firms relative to non-energy-intensive firms in each quarter from 2021Q2 onwards relative to the 2020Q1-2021Q2 period. We chose 2020Q1-2021Q1 as the reference period, as energy prices during that period were stable. However, as credit growth during that period was volatile because of the Covid-19 pandemic, we normalize to the average over the entire period instead of a single quarter to smooth out this volatility.

Our baseline model defines firms as high-energy-intensive if their average energy intensity between 2012 and 2020 is above the median energy intensity for that period. The underlying idea is that a firm's energy intensity level determines its exposure to energy price shocks. This assumption can be problematic if there is perfect sorting regarding energy intensity across industries. Consider the example that all firms in one industry are in the low-energy-intensity group, while all firms in a second industry are in the high-energy-intensity group. In this case, the high-energy-intensity dummy would be perfectly collinear with the fixed effect of the industry. However, our data shows variation in energy intensity within and across industries.

4 Effects on Firm Credit Growth

First, we show the effect of the energy price shock on all energy-intensive firms, showing that, on average, their credit growth fell after the invasion due to the shock. This fall in credit growth is concentrated among firms with high energy intensity, supporting the hypothesis that energy intensity and not some other unobserved characteristic drives this result. The result is robust to different measures of energy intensity. We also demonstrate that accounting for industry-time fixed effects is important.

4.1 Decline in Average Credit Growth

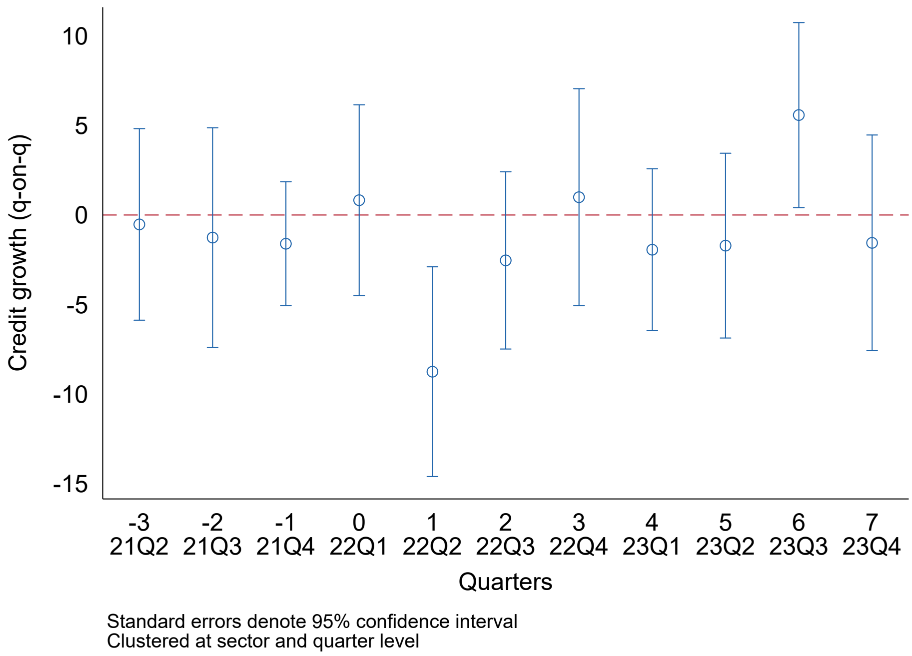


Figure 4: Effects of the energy price shock on credit growth

Note: This figure reports the coefficients β_τ obtained by estimating equation 3.2. Period: 2019Q4-2023Q4. Source: Credit register, ENERGI, FIRE, FIRM and own calculations.

Column 1 of Table 1 and Figure 4 show that the credit growth of high-energy-intensity firms fell by 8.75 percentage points relative to the credit growth of low-energy-intensity firms in 2022Q2, the quarter following the Russian invasion of Ukraine and the quarter where Russia shut off its gas supply to Denmark. Before that, credit growth was not significantly different for the two groups of firms. Credit growth recovers in the quarters after 2022Q2, but the difference is not statistically significant.

Columns 2 to 5 of Table 1 and Figure 12 in Appendix B.2 show that controlling for industry × time fixed effects is crucial to remove differences in trends across high- and low-energy-intensity firms.

Table 1: Baseline results

Note: This table shows results of estimating alternative versions of equation 3.2. It reports the β_{2022Q2} coefficients, with t-statistics in parentheses. The dependent variable is credit growth, as defined in equation 2.1. Column 1 is the baseline, with firm fixed effects, four-digit industry $\times$ time fixed effects and bank $\times$ time fixed effects. Column 2 removes firm fixed effects, Column 3 removes firm and bank $\times$ time fixed effects, Column 4 removes firm and industry $\times$ time fixed effects, and Column 5 removes all fixed effects. In all columns, residuals are clustered at the industry and time level. Estimation sample: 2020Q1-2023Q4.

	(1)	(2)	(3)	(4)	(5)
High EI $\times$ 22Q2	-8.753**	-9.014**	-9.578***	-5.757***	8.449**
	(-3.18)	(-4.01)	(-4.23)	(-4.51)	(3.33)
Firm FE	Yes	No	No	No	No
Sector $\times$ Time FE	Yes	Yes	Yes	No	No
Bank $\times$ Time FE	Yes	Yes	No	Yes	No
R2	0.129	0.108	0.0892	0.0284	0.00163
Obs.	43281	43317	43336	44172	44191

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4.2 Decline in the Average Level of Credit

The relative decline in credit growth implies that the *level* of credit of high-energy-intensity vs. low-energy-intensity firms fell temporarily and then recovered slowly when energy prices dropped, although not to pre-shock levels. To illustrate this, we estimate the following lag-augmented local projection (Jordà 2005; Montiel Olea and Plagborg-Møller 2021):

$$credit\_growth_{fb,\tau,\tau+h} = \alpha^h + \beta^h 1_{\bar{EI}_f=high} + \gamma^h C_{fb,\tau-1} + \delta^h_{sector_f} + \delta^h_b + \varepsilon_{fb,\tau,\tau+h}. \tag{4.1}$$

$credit\_growth_{fb,\tau,\tau+h}$ is the cumulative credit growth between the reference period τ and period $\tau + h$, computed as

$$credit\_growth_{fb,\tau,\tau+h} = \frac{C_{fb,\tau+h} - C_{fb,\tau}}{0.5\left(C_{fb,\tau+h} + C_{fb,\tau}\right)}. \tag{4.2}$$

h is the estimation horizon. α^h is a horizon-specific constant. $1_{\bar{EI}_f=high}$ is, as before, a dummy for high energy intensity. Following Montiel Olea and Plagborg-Møller (2021), we include lagged credit $C_{fb,\tau-1}$, as that eliminates autocorrelation of residuals. $\delta^h_{sector_f}$ and δ^h_b are horizon-specific industry and bank fixed effects, fulfilling a similar role as the industry-time and bank-time fixed effects in 3.2. We use heteroskedasticity-robust standard errors, as recommended by Montiel Olea and Plagborg-Møller (2021). The coefficients of interest are the $\left\{\beta^h\right\}^{T_2}_{h=-T_1}$. They measure the cumulative impulse response of the level of credit to the energy price shock.

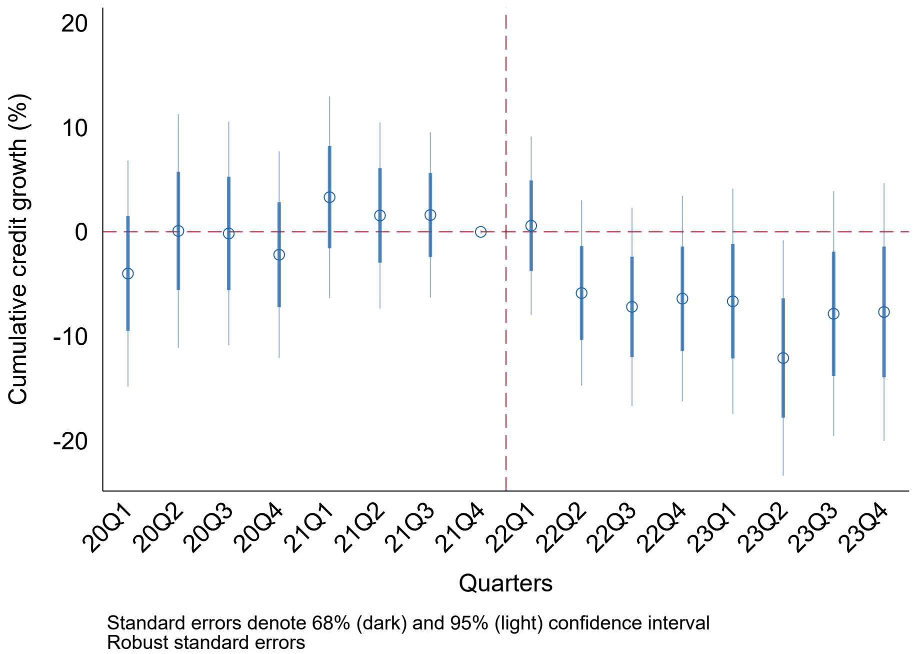


Figure 5: Cumulative effect of the energy price shock on the level of credit

Note: This figure reports the coefficients β^h obtained by estimating equation 4.1. Period: 2019Q4-2023Q4. Source: Credit register, ENERGI, FIRE, FIRM and own calculations.

Figure 5 shows that energy-intensive firms' credit levels fell persistently and significantly, recovering only towards the end of the sample. We use the fourth quarter of 2021, the last quarter before the invasion, as the reference period. We report both 68 per cent and 95 per cent confidence intervals, as local projections are notorious for their high standard errors (Li, Plagborg-Møller, and Wolf 2024).

Before the last quarter of 2021, there was no difference in the level of credit between high-energy-intensity and low-energy-intensity firms. In the first quarter of 2022, the quarter of the invasion, there was no effect, but in the second quarter of 2022, when Russia shut off its gas supply to Denmark, credit started to fall, falling by 12 percentage points at its trough in the second quarter of 2023. This fall is significant at the 95 per cent confidence level. Credit then slowly recovered to its pre-shock level but had not returned to it by the end of the fourth quarter of 2023.

4.3 Alternative Specifications and Robustness

Next, we will show three robustness checks that support the causal interpretation of the fall in credit growth. First, the effect of the energy shock on firms' credit growth is monotonically increasing in energy intensity, suggesting that the energy price shock indeed drives the observed decline in credit growth. Second, different measures of energy intensity lead to similar results. Third, in horse race regressions with other firm characteristics, the difference in energy intensity remains the main driver in the observed credit growth differences.

4.3.1 Finer Quantiles

Column 7 of Table 2 and Figure 10 show that the decline in credit growth is concentrated among high-energy-intensity firms. For this figure, we estimate an alternative specification where we replace the high energy intensity dummy in equation 3.2 with dummies for the 25%-50%, 50%-75%, 75%-95% and 95%-100% quantiles of the energy intensity distribution. The coefficients report the difference in credit growth of these quantiles relative to the 0%-25% quantile.

There is no differential effect on credit growth for firms in the 25-50 per cent quantile and in the 50-75 per cent quantile. These firms have, on average, low energy intensities of 0.9 and 2 per cent, respectively. Above the 75 per cent quantile, there is a decline in credit growth in the second quarter of 2022, which is most pronounced for the firms in the top five per cent of the energy intensity distribution. Firms in these top quantiles have high energy intensities of 4.6 and 15.5 per cent, respectively. These results suggest that the energy price shock and not any other unobserved effect drive the results.

4.3.2 Alternative Definitions of Energy Intensity

Table 2 and Figure 11 in Appendix B.2 show that the main result is robust to various changes in specification. We introduce the robustness checks and then discuss how they compare to the baseline specification.

Within-sector energy intensity dummies Alternatively to the baseline specification, we define firms as high-energy-intensive if their average energy intensity between 2012 and 2020 is high relative to the median energy intensity in their two-digit industry. This definition assumes that the rank of a firm's energy intensity within its industry determines its exposure to energy price shocks, which is harder to justify. However, this specification does not suffer from the issue of sorting firms into industries with different energy intensities. The results are reported in Column 1 of Table 2 and Panel 11a of Figure 11.

Energy price change The level of energy intensity might not be relevant if firms have long-term energy contracts and are therefore not immediately exposed to the energy price

Table 2: Alternative measures of energy intensity

Note: This table shows variants of equation 3.2, where we replace energy intensity with alternative measures. It reports the β_{2022Q2} coefficients, with t-statistics in parentheses. The dependent variable is credit growth, as defined in equation 2.1. Column 1 splits firms at the median of revenue-based energy intensity within two-digit industries. Column 2 splits firms at the 75th percentile of the change in energy intensity. Column 3 splits firms at the median of technology-based energy intensity. Columns 4, 5, and 6 use measures of revenue-based energy intensity that include only natural gas expenditures, electricity expenditures and the sum of natural gas and electricity expenditures, respectively. Column 7 splits the sample at the median and the 25%, 75%, and 95% quantiles. Column 8 includes the log of energy intensity, standardized to have zero mean and unit variance, as a continuous variable. All specifications include firm fixed effects, four-digit industry × time fixed effects and bank × time fixed effects. In all columns, residuals are clustered at the industry and time level. Estimation sample: 2020Q1-2023Q4.

	(1) Within EI	(2) EI Change	(3) Tech EI	(4) Gas & El.	(5) Only Gas	(6) Only El.	(7) Finer Dummies	(8) Continuous EI
High EI × 22Q2	-9.748***							
	(-5.10)							
High Δ EI × 22Q2		-8.543**						
		(-3.52)						
High EI × 22Q2			-7.888**					
			(-3.26)					
High Gas & El. × 22Q2				-7.134*				
				(-2.44)				
High Gas × 22Q2					2.190			
					(1.08)			
High El. × 22Q2						-7.284*		
						(-2.52)		
25%-50% × 22Q2							-2.816	
							(-0.68)	
50%-75% × 22Q2							-7.096	
							(-1.34)	
75%-95% × 22Q2							-15.36**	
							(-3.14)	
95%-100% × 22Q2							-26.55**	
							(-3.84)	
EI × 22Q2								-5.971**
								(-3.55)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector × Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank × Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.129	0.128	0.130	0.129	0.129	0.129	0.131	0.130
Obs.	43281	46415	43755	43281	43281	43281	43281	42891

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

shock. Therefore, we alternatively use the change in energy intensity between 2020 and 2022 as an alternative measure of firms' exposure to the energy price shock. We split firms at the 75th percentile of the change in energy intensity. The results are reported in Column 2 of Table 2 and Panel 12f of Figure 12.

Technology-based energy intensity One concern with the revenue-based measure of energy intensity is that it fluctuates over time because of short-run fluctuations in energy prices and revenue. We, therefore, also use an alternative, technology-based energy intensity of firm i as

$$EI_{ft}^{tech} = \frac{energy\_gj_{ft}}{employment_{ft}}. \tag{4.3}$$

$energy\_gj_{ft}$ is the energy consumption of firm i in gigajoule (GJ) and $employment_{ft}$ is the employment of firm f in full-time equivalent units. EI_{ft}^{tech} is the annual usage of energy per employee, expressed in GJ per employee. The results are reported in Column 3 of Table 2 and Panel 11c of Figure 11.

Different types of energy We compute different measures of revenue-based energy intensity based on total energy consumption, gas & electricity consumption, gas consumption, and electricity consumption. The results are reported in Columns 4, 5, and 6 of Table 2 and Panels 11d to 11f of Figure 11.

Continous measure of energy intensity Another concern is that the choice of quantiles is arbitrary. We, therefore, also use a continuous measure of energy intensity, computed as the natural logarithm of energy intensity and standardized to have zero mean and unit variance. We use the logarithm of energy intensity, as energy intensity transformed in this way has a bell-shaped distribution, resembling a normal distribution. The results are reported in Column 8 of Table 2 and Panel 11b of Figure 11.

These different measures of energy intensity lead to similar results. One exception is a specification of only gas-intensive firms. This is likely because there is not enough variation in gas intensity across firms to obtain meaningful results.

4.3.3 Horse Race Regressions with Other Firm Characteristics

Figure 13 and Table 11 in Appendix B.3 show that the effect is due to differences in treatment and control firms' energy intensity, not size, age, or leverage. To establish this result, we estimate variants of equation 3.2 where we control for interactions between, respectively, size quantiles and time dummies, age quantiles and time dummies, leverage quantiles and time dummies, or all three interactions. The estimated effect in 2022Q2 (first line in Table 11) remains stable across these different specifications.

5 Credit Supply and Demand Channels

In light of the reduction in average credit growth following the energy price shock (see section 4.1), we now analyse in more detail how credit was affected to determine whether this decline resulted from reduced credit demand, reduced credit supply, or both. First, we investigate which credit components (instrument types, new versus preexisting credit and credit limits versus utilisation) were most affected. Second, we investigate whether the credit growth effect depends on firm characteristics, such as size and age.

5.1 Decomposition of Credit

We begin by decomposing credit into its various components. We first break it down into different instrument types and then into new versus preexisting loans.

Suppose there are J components, so that, $C_{fbt} \equiv C^1_{fbt} + \ldots + C^J_{fbt}$, where C^j_{fbt} is credit corresponding to component j. Taking the first differences and dividing by the average of total credit between $t-1$ and t, we obtain,

$$credit\_growth_{fbt} = growth\_cont^1_{fbt} + \ldots + growth\_cont^J_{fbt}, \tag{5.1}$$

where

$$growth\_cont^j_{fbt} \equiv 100 \times \frac{C^j_{fbt} - C^j_{fbt-1}}{0.5\,(C_{fbt} + C_{fbt-1})}, \tag{5.2}$$

is the contribution (in percentage points) to overall credit growth coming from component j. The sum of these growth contributions across all components equals the total credit growth for the firm-bank observation. We then replace credit growth in equation 3.2 with these growth contribution terms. By construction, since these decomposed regressions contain the same regressors as the original regression (equation 3.2), the coefficients from the decomposed regressions will sum up to the coefficient in equation 3.2. In other words, the coefficient in the regression corresponding to component j will measure the credit growth effect coming from component j of the energy price shock.

5.1.1 Large Contribution from Credit Lines and Credit Cards

There are several types of credit instruments, ranging from credit lines to mortgage loans. Knowing which types of credit were affected the most by the energy shock is useful as different instruments are used for different purposes (e.g. to ensure liquidity or to finance long-term investments). The top panel of Table 3 and Figure 6 show the results from regressions corresponding to the various instrument types.

Credit lines and credit cards drive the decline in credit growth. The single largest contribution comes from credit lines, which explain about 70 per cent of the decline in average credit growth. The remainder comes from credit cards. There is also a small decline in the growth of mortgages and other C&I loans, which are quantitatively less important. Trade credit and leasing do not change.

5.1.2 Large Contribution from Preexisting Loans

Next, we investigate whether new or preexisting loans drove the decline in credit growth. We define a loan as new if issued in the current quarter and as preexisting if issued before the current quarter. The middle and bottom panels of Table 3 show the decomposition into credit growth of new as opposed to preexisting loans for the different types of credit. The decline in credit is almost entirely because of a decline in preexisting loans, not new loans. Almost 55 per cent of the decline is due to a decline in preexisting credit lines, and another 30 per cent is due to a decline in preexisting credit cards.

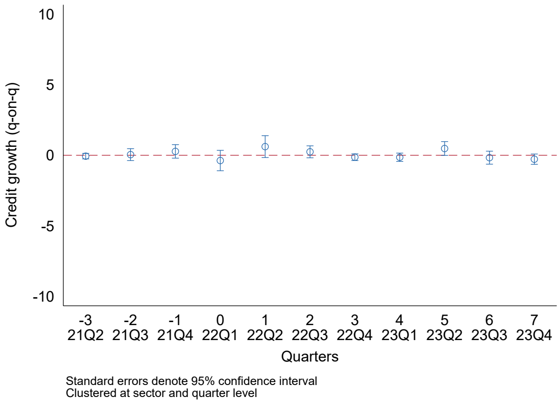
5.1.3 Large Contribution of Firms' Utilization of Preexisting Credit Lines

The drop in preexisting credit lines, which drives the reduction in average credit growth, could reflect that firms chose lower utilization rates. This is a demand interpretation. However, it could also be because banks lowered credit limits (the maximum withdrawal on overdrafts) when limits were binding. That would instead suggest that banks tightened the credit supply.

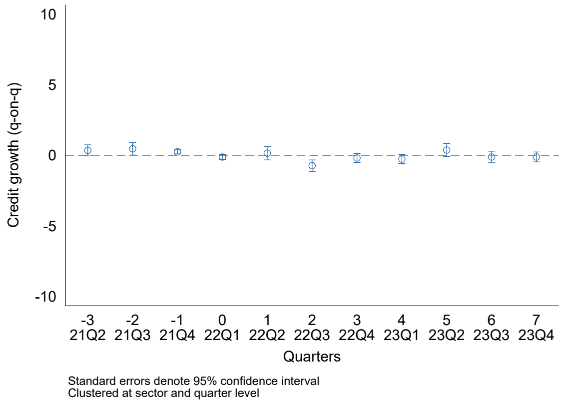
The credit register contains information about the credit limit for a subset of loans, which allows us to investigate whether the reduction was due to lower utilization or lower credit limits. In order to decompose the contribution to average credit growth from preexisting credit lines further into effect contributions from lower utilization and lower credit limits, start by defining $growth\_cont_{fbt}^{credit\_line}$ as the contribution to overall credit growth from the component corresponding to credit lines according to equation 5.2. Let $L_t^{credit\_line} > 0$ denote the limit on the credit line and U_t the utilization rate of the credit line. We can then rewrite the level of credit as

$$C_{fbt}^{credit\_line} = U_{fbt}^{credit\_line} L_{fbt}^{credit\_line}. \tag{5.3}$$

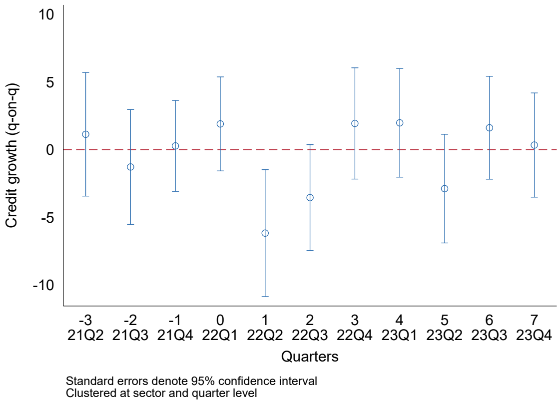
Taking first differences and rearranging terms, we can then compute the contributions of



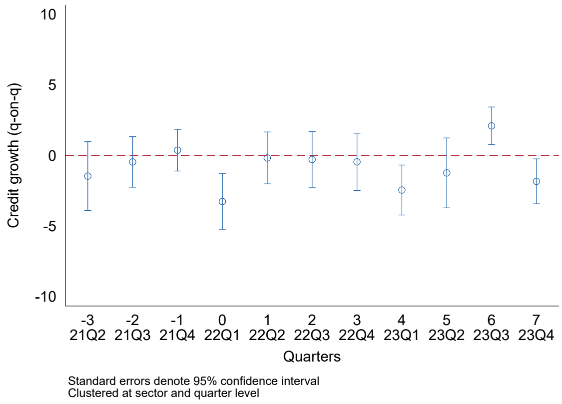
(a) Trade credit



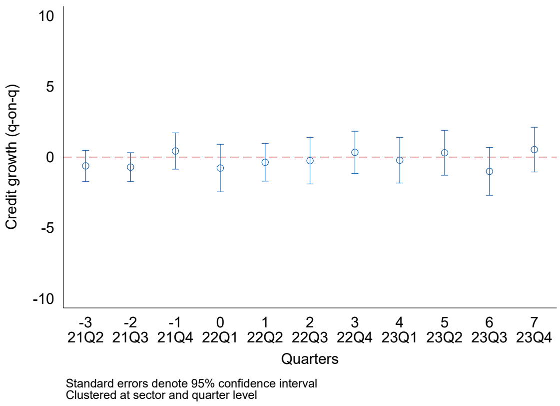
(b) Mortgages



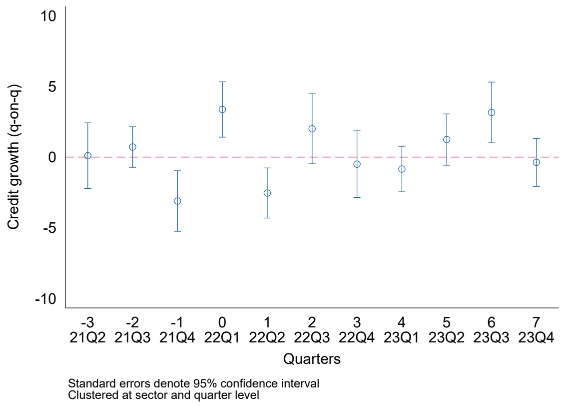
(c) Credit lines



(d) Other C&I loans



(e) Leasing



(f) Credit cards

Figure 6: Contributions of different types of credit to overall credit growth

Note: This figure shows the results of estimating a variant of equation 3.2 for the contributions of different types of credit to overall credit growth, as defined in equation 5.2. Period: 2019Q4-2023Q4. Source: Credit register, ENERGI, FIRE, FIRM and own calculations.

Table 3: Decomposition of credit growth

Note: This table shows results of estimating alternative versions of equation 3.2, replacing credit growth with its decomposition 5.2 into contributions of growth in various credit types to overall credit growth. It reports the β_{2022Q2} coefficients, with t-statistics in parentheses. The top panel reports estimates for all loans, the middle panel estimates for loans issued in the current quarter (new loans), and the bottom panel estimates for loans issued before the current quarter (preexisting loans). All specifications include firm fixed effects, four-digit industry × time fixed effects and bank × time fixed effects. In all columns, residuals are clustered at the industry and time level. Estimation sample: 2020Q1-2023Q4.

(a) All loans

	(1) All Loans	(2) Trade Credit	(3) Mortgages	(4) Credit Lines	(5) Term Loans	(6) Leasing	(7) Credit Cards	(8) Other Loans
High EI × 22Q2	-8.753**	0.615	0.150	-6.167*	-0.174	-0.368	-2.540**	-0.269
	(-3.18)	(1.69)	(0.67)	(-2.80)	(-0.20)	(-0.59)	(-3.06)	(-1.74)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector × Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank × Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.129	0.164	0.177	0.129	0.127	0.174	0.146	0.0466
Obs.	43281	43281	43281	43281	43281	43281	43281	43281

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

(b) New loans

	(1) All Loans	(2) Trade Credit	(3) Mortgages	(4) Credit Lines	(5) Term Loans	(6) Leasing	(7) Credit Cards	(8) Other Loans
High EI × 22Q2	-0.468	-0.0145	0.206	-1.358*	0.333	0.678	-0.0430	-0.269
	(-0.58)	(.)	(0.87)	(-2.28)	(0.57)	(2.08)	(.)	(-1.74)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector × Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank × Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.124	0.273	0.105	0.135	0.112	0.118	0.0993	0.0466
Obs.	43281	43281	43281	43281	43281	43281	43281	43281

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

(c) Preexisting loans

	(1) All Loans	(2) Trade Credit	(3) Mortgages	(4) Credit Lines	(5) Term Loans	(6) Leasing	(7) Credit Cards	(8) Other Loans
High EI × 22Q2	-8.285**	0.629	-0.0561	-4.808*	-0.507	-1.046	-2.497*	0
	(-3.52)	(1.72)	(-0.21)	(-2.53)	(.)	(-1.95)	(-2.79)	(.)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector × Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank × Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.129	0.150	0.149	0.126	0.125	0.163	0.147	.
Obs.	43281	43281	43281	43281	43281	43281	43281	43281

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

these two components to overall credit growth as

$$growth\_cont^{utilization}_{fbt} = 100 \times \frac{\left(U^{credit\_line}_{fbt} - U^{credit\_line}_{fbt-1}\right) L^{credit\_line}_{fbt}}{0.5\left(C_{fbt} + C_{fbt-1}\right)}, \tag{5.4}$$

$$growth\_cont^{credit\_limit}_{fbt} = 100 \times \frac{\left(L^{credit\_line}_{fbt} - L^{credit\_line}_{fbt-1}\right) U^{credit\_line}_{fbt-1}}{0.5\left(C_{fbt} + C_{fbt-1}\right)}. \tag{5.5}$$

Table 4 shows the results. Because credit limit information is not available for all observations on credit lines, we re-estimate the total effect in column 1. This data limitation cuts our sample size by 60 per cent, making the estimates insignificant at the five per cent level. Nevertheless, the point estimates are close to those for the full sample.

In column 2, we show that about 55 per cent of the total effect stems from credit lines. About 68 per cent of the decline in credit lines is because of a decline in utilization, with the remainder stemming from a decline in credit limits. For preexisting credit lines, it is even more pronounced that the decline in utilization is the most important component, while credit limits move in the opposite direction. The decline in the utilization of preexisting credit lines alone explains about 42 per cent of the total decline in credit growth. The importance of credit line utilization suggests that credit demand was an important driver of the fall in credit growth.

5.2 The Role of Firm Characteristics

We next investigate heterogeneity in the effects of the energy price shock on the credit of different types of firms. This exercise is helpful, as the impact of the energy price shock on different groups of firms is informative about whether credit supply or credit demand drives the main result. We sort firms into groups based on their lagged firm characteristics to establish this result. We then estimate the following regression:

$$\begin{aligned} credit\_growth_{fbt} = \alpha &+ \sum_{\tau=T_1}^{T_2} \beta^1_\tau \left(1_{\bar{EI}_f=high} \times 1_{\text{Group }1,ft} \times 1_{t=\tau}\right) \\ &+ \sum_{\tau=T_1}^{T_2} \beta^2_\tau \left(1_{\bar{EI}_f=high} \times 1_{\text{Group }2,ft} \times 1_{t=\tau}\right) \\ &+ \sum_{\tau=T_1}^{T_2} \gamma_\tau \left(1_{\text{Group }2,ft} \times 1_{t=\tau}\right) + \delta_f + \delta_{industry(f)t} + \delta_{bt} + \varepsilon_{fbt} \end{aligned} \tag{5.6}$$

The coefficients of interest are the β^1_τ and β^2_τ coefficients. They measure group-specific causal effects of the energy price shock.[16] For example, if we sort firms according to their

16. One concern with this specification is that group-specific medians of energy intensity could differ across groups. In unreported results, we have checked this and found that both group-specific means

Table 4: Decomposition of credit line growth contribution into components

Note: This table shows results of estimating alternative versions of equation 3.2, replacing credit growth with its decomposition 5.2 into contributions of growth in credit line utilization and credit limits to overall credit growth. Because credit limit information is not available for all loans, we rely on a smaller sample and have re-estimated the total effect (column 1). The table reports the β_{2022Q2} coefficients, with t-statistics in parentheses. The top panel reports estimates for all loans, and the bottom panel estimates for loans issued before the current quarter (preexisting loans). All specifications include firm fixed effects, four-digit industry $\times$ time fixed effects and bank $\times$ time fixed effects. In all columns, residuals are clustered at the industry and time level. Estimation sample: 2020Q1-2023Q4.

(a) All credit lines

	(1) All Loans	(2) Credit Lines	(3) Credit Limit	(4) Utilization
High EI $\times$ 22Q2	-9.280	-5.071	-1.626	-3.444
	(-1.77)	(-1.02)	(-1.03)	(-0.78)
Firm FE	Yes	Yes	Yes	Yes
Sector $\times$ Time FE	Yes	Yes	Yes	Yes
Bank $\times$ Time FE	Yes	Yes	Yes	Yes
R2	0.215	0.219	0.246	0.221
Obs.	16474	16474	16474	16474

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

(b) Preexisting credit lines

	(1) All Loans	(2) Credit Lines	(3) Credit Limit	(4) Utilization
High EI $\times$ 22Q2	-6.695	-3.021	0.920	-3.941
	(-1.19)	(-0.58)	(0.62)	(-0.86)
Firm FE	Yes	Yes	Yes	Yes
Sector $\times$ Time FE	Yes	Yes	Yes	Yes
Bank $\times$ Time FE	Yes	Yes	Yes	Yes
R2	0.215	0.216	0.236	0.221
Obs.	16005	16005	16005	16005

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

riskiness into a safe and a risky group, we would have four groups of firms: safe low-energy-intensity firms, risky low-energy-intensity firms, safe high-energy-intensity firms and risky high-energy-intensity firms. β^1_τ measures the change in credit growth of safe high-energy-intensity firms relative to safe low-energy-intensity firms. β^2_τ measures the change in credit growth of risky high-energy-intensity firms relative to risky low-energy-intensity firms. γ_τ measures the change in credit growth of risky low-energy-intensity firms relative to safe low-energy-intensity firms. And $\beta^2_\tau + \gamma_\tau$ measures the change in credit growth of risky high-energy-intensity firms relative to safe low-energy-intensity firms.

We discuss three sources of heterogeneity: debt maturity, ex-ante riskiness, and liquidity.

5.2.1 Larger Effect for Firms with Higher Share of Debt Due in Second Quarter of 2022

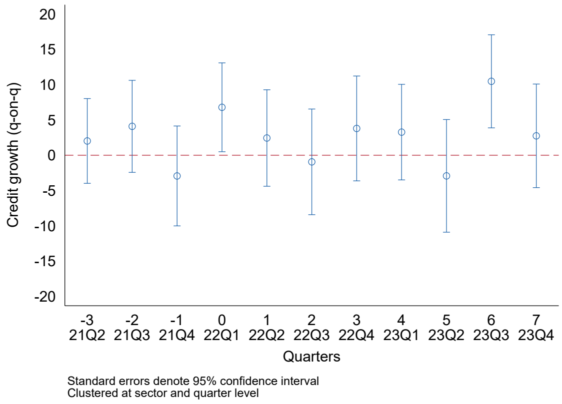
We first investigate whether the share of debt due in the second quarter of 2022 matters for the credit growth effect of the energy price shock. The share of debt that is due when a shock happens is a measure of the financial exposure of firms to the shock.[17] Suppose firms with a high share of debt maturing in the second quarter of 2022 respond more strongly to the shock. In that case, we interpret this as evidence that firms' financial conditions are key to understanding the impact of the energy price shock.

We measure the share of debt coming due in the next quarter as the share of all debt with a maturity of 90 days or less at the end of the quarter. We treat debt without maturity date as zero maturity debt. We then split firms into two groups at the median of the share of debt due in the second quarter of 2022. We expect β^2_{2022Q2} is bigger than β^1_{2022Q2}, i.e. that firms with a high share of debt coming due in the second quarter of 2022 will respond more to the energy price shock than firms with a low share of debt coming due.

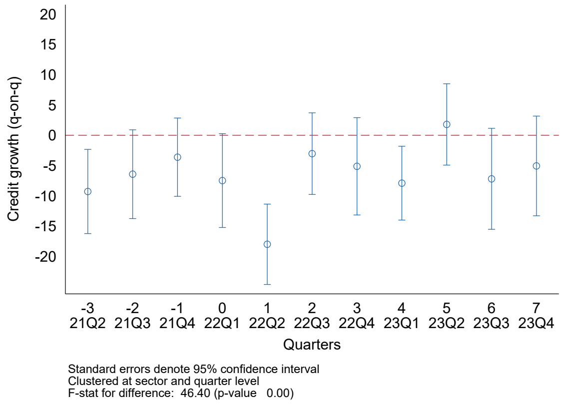
Column 1 of Table 5 and Panels 7a and 7b of Figure 14 show that high-energy-intensity firms with a low share of debt coming due in 2022Q2 did not reduce credit growth relative to low-energy-intensity firms with a low maturing debt share, as β^1_{2022Q2} is not significant at conventional levels. In contrast, high-energy-intensity firms with a high share of debt coming due in 2022Q2 reduced credit growth by $\beta^2_{2022Q2} = 18$ percentage points relative to low-energy-intensity firms with a high maturing debt share and by $\beta^2_{2022Q2} + \gamma_{2022Q2} = 14$ percentage points relative to low-energy-intensity firms with a low maturing debt share. This finding shows that firms' financial conditions are central to understanding the impact

and group-specific medians are similar across groups.

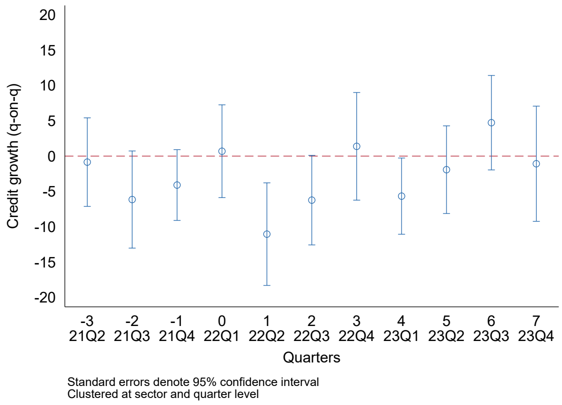
17. Duchin, Ozbas, and Sensoy (2010) and Almeida, Campello, Laranjeira, and Weisbrenner (2012) use heterogeneity in debt maturity to study the effects of the financial crisis, Buera and Karmakar (2022) and Kalemli-Özcan, Laeven, and Moreno (2022) the effects of the European sovereign debt crisis and Jungherr et al. (2022) the effects of monetary policy shocks.



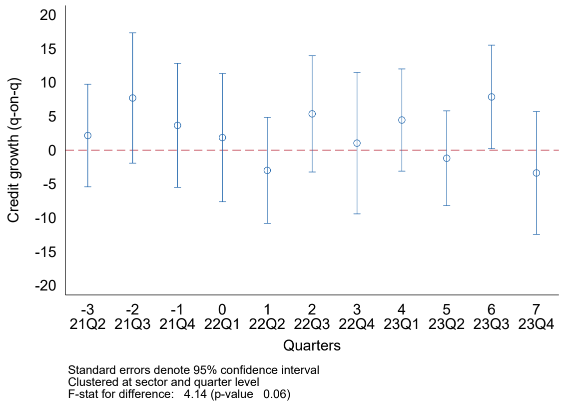
(a) Low share of debt due in 2022Q2



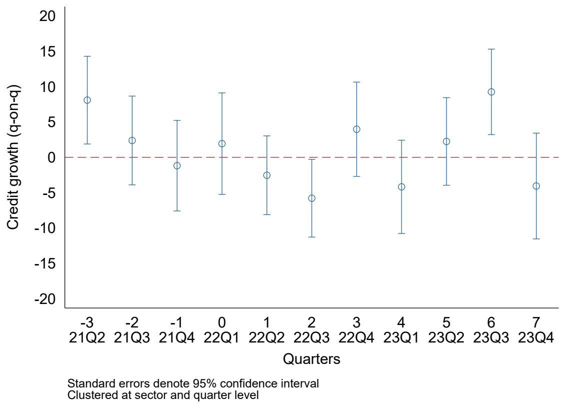
(b) High share of debt due in 2022Q2



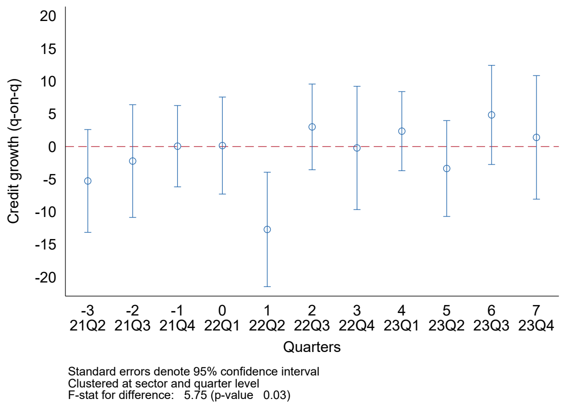
(c) Low-risk firms



(d) High-risk firms



(e) Low liquidity firms



(f) High liquidity firms

Figure 7: Effects of the energy price shock on the credit growth of different types of firms

Note: This figure shows the results of estimating equation 5.6. Period: 2019Q4-2023Q4. Source: Credit register, ENERGI, FIRE, FIRM and own calculations.

Table 5: Heterogeneous effects on credit growth

Note: This table shows results of estimating alternative versions of equation 5.6. It reports the β^1_{2022Q2}, β^2_{2022Q2} and γ_{2022Q2} coefficients, with t-statistics in parentheses. The dependent variable is credit growth, as defined in equation 2.1. All specifications include firm fixed effects, four-digit industry × time fixed effects and bank × time fixed effects. Column 1 splits firms at the median by the share of debt maturing in the second quarter of 2022. Column 2 splits firms according to their ex-ante bank-reported default probability at the 75th percentile. Column 3 splits firms according to their number of employees, with firms with less than 90 employees classified as small and firms with more than 90 employees classified as large. Column 4 splits firms according to age, with firms aged 20+ years classified as old. Column 5 splits firms according to the median ratio of current assets, excluding inventories and current liabilities in 2021. In all columns, residuals are clustered at the industry and time level. Estimation sample: 2020Q1-2023Q4.

	(1) Maturity	(2) Riskiness	(3) Size	(4) Age	(5) Liquidity
High EI × 22Q2 × low share of debt due	2.442				
	(0.76)				
High EI × 22Q2 × high share of debt due	-17.98***				
	(-5.78)				
22Q2 × high share of debt due	3.530				
	(1.38)				
High EI × 22Q2 × low def. risk		-11.04**			
		(-3.24)			
High EI × 22Q2 × high def. risk		-2.989			
		(-0.81)			
22Q2 × high def. risk		-11.02**			
		(-2.97)			
High EI × 22Q2 × small firm			-13.40**		
			(-3.95)		
High EI × 22Q2 × large firm			4.232		
			(1.00)		
22Q2 × large firm			-12.96*		
			(-2.62)		
High EI × 22Q2 × young firm				-11.53*	
				(-2.24)	
High EI × 22Q2 × old firm				-7.917*	
				(-2.45)	
22Q2 × old firm				0.477	
				(0.14)	
High EI × 22Q2 × low liquidity					-2.542
					(-0.97)
High EI × 22Q2 × high liquidity					-12.70**
					(-3.09)
22Q2 × high liquidity					14.77**
					(3.70)
Firm FE	Yes	Yes	Yes	Yes	Yes
Sector × Time FE	Yes	Yes	Yes	Yes	Yes
Bank × Time FE	Yes	Yes	Yes	Yes	Yes
R2	0.129	0.130	0.130	0.130	0.129
Obs.	41611	43281	43281	43281	43184
F-test $\beta^1 = \beta^2$	46.40	4.143	14.94	0.410	5.745
p-value	0.00000587	0.0599	0.00153	0.531	0.0300
F-test $\beta^2 + \gamma = 0$	13.59	8.167	2.406	3.692	0.333
p-value	0.00220	0.0120	0.142	0.0739	0.572

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

of the energy price shock.

5.2.2 Larger Effect for Less Risky Firms

Different effects of the energy price shock on low-risk firms and high-risk firms could arise because credit terms of high-risk firms are more sensitive to macroeconomic shocks or because riskier firms are more financially constrained (Alfaro et al. 2023; Palazzo and Yamarthy 2022). However, riskier firms may also have less elastic credit demand. Therefore, we interpret the response of less risky firms to the energy price shock as evidence of a credit demand channel. In contrast, we interpret the response of more risky firms as evidence for a credit supply channel. We sort firms into low-risk and high-risk groups by splitting them at the 75th percentile according to their lagged, bank-reported probability of default between 2019Q4 and 2021Q4. We use the 75th percentile because the median default probability is very low.

Column 2 of Table 5 and Panels 7c and 7d of Figure 7 shows that high-energy-intensive firms with low ex-ante riskiness had reduced credit growth of $\beta^1_{2022Q2} = 11$ percentage points relative to low-energy-intensive firms. High-energy-intensity firms with higher ex-ante riskiness had reduced credit growth by $\beta^2_{2022Q2} = 3$ percentage points relative to low-energy-intensity firms with higher ex-ante riskiness. However, this effect is not significantly different from zero at conventional significance levels. The difference in the coefficients β^1_{2022Q2} and β^2_{2022Q2} between low-risk and high-risk firms in 2022Q2 is statistically significant at the ten per cent level. We interpret this stronger response of *less* risky firms as evidence that a decline in credit demand drives the decline in credit growth.

This does not mean high-risk, high-energy-intensity firms did not reduce credit growth. Relative to low-risk firms, high-risk firms had reduced credit growth by 11 percentage points. Therefore, high-risk and high-energy-intensity firms reduced credit growth by $\beta^2_{22Q2} + \gamma_{22Q2} = 14$ percentage points relative to low-risk low-energy-intensity firms. In contrast, low-risk and high-energy-intensity firms reduced credit growth by only $\beta^1_{22Q2} =$ 11 percentage points relative to low-risk low-energy-intensity firms.

5.2.3 Larger Effect for Firms with more Cash

Finally, we consider heterogeneity in liquidity. We measure liquidity as the ratio of current assets excluding inventories, divided by current liabilities, and split firms at the median of this ratio in 2021. Low liquidity firms are likelier to be liquidity-constrained (Duchin et al. 2010; Bolton et al. 2011; Eisfeldt and Muir 2016). We expect that liquidity-constrained firms have a less elastic credit demand in response to the shock, so they are more affected by credit supply conditions. We expect that unconstrained firms at risk of becoming liquidity-constrained have a more elastic credit demand to the shock, such that their dynamics are more informative about credit demand conditions.

Column 5 of Table 5 and Panels 7e and 7f of Figure 14 show that high-energy-intensity firms with low liquidity did have reduced credit growth relative to low-energy-intensity firms with low liquidity, i.e. β^1_{2022Q2} is positive, but not significant. High-energy-intensity firms with high liquidity had reduced credit growth relative to low-energy-intensity firms with high liquidity, i.e. β^2_{2022Q2} is positive and strongly significant. γ_{2022Q2} is positive, suggesting that low-energy-intensity firms with low liquidity had lower credit growth than low-energy-intensity firms with high liquidity. These findings suggest that liquidity played a role in the effects of the energy price shock, likely by inducing firms at the risk of becoming liquidity-constrained to borrow less. Therefore, this result supports our interpretation that the decline in credit growth is because of a precautionary decline in credit demand. Appendix C shows that larger and younger firms had a stronger decline in credit growth, further supporting the credit demand explanation.[18]

6 Effects on Loan Terms of New Loans

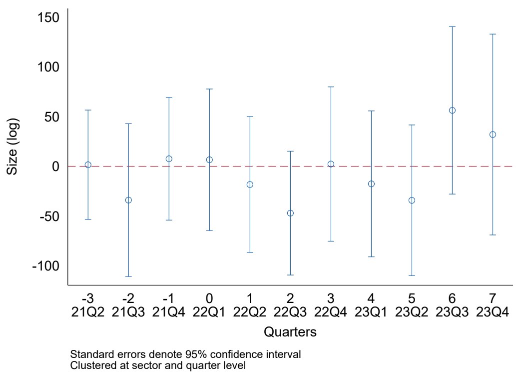
The above results show that the drop in average credit growth is largely because of a reduction in preexisting loans. However, the smaller response in new loans does not indicate that nothing happened to the demand and supply on the market for new loans. In particular, it might be that banks tightened the loan terms on new loans - i.e. credit supply, but at the same time, the demand for new loans increased to the extent that the traded amount of new loans was roughly unchanged.

6.1 Tightening of loan terms at the firm-bank level

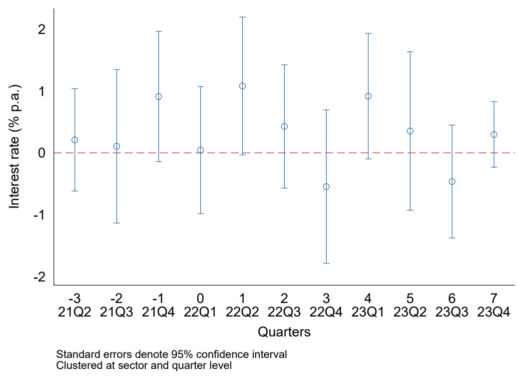
To investigate whether credit supply, through new loans, could have been tightened, we now investigate whether the terms of new loans changed due to the energy price shock. We define a loan as new if issued in the current quarter. There are four main loan terms of interest: the size, interest rate on the loan, maturity, and collateral requirement. We expect a tightening of credit supply would be reflected in smaller loans, higher interest rates, shorter loan maturities, and higher collateral requirements.

Figure 8 shows the results where we estimate variants of specification 3.2 at the firm level, replacing credit growth with the loan terms on new loans. There is no effect on loan size. However, interest rates on new loans and the share of collateralized loans rise,

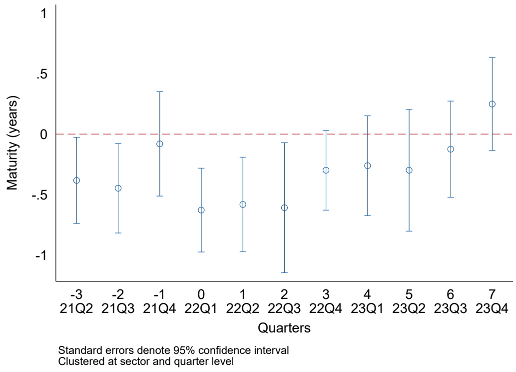
18. The idea here is that larger and younger firms are less constrained and, therefore, more likely to manage their liquidity actively.



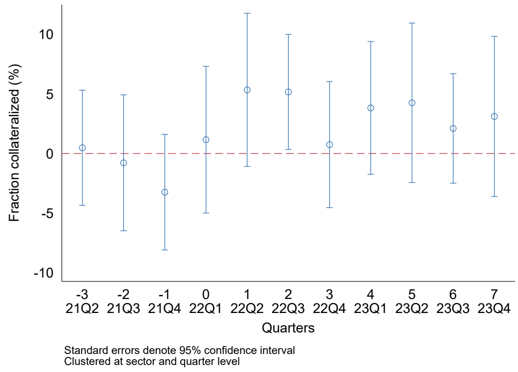
(a) Loan size



(b) Interest rate



(c) Maturity



(d) Share collateralized

Figure 8: Effects of the energy price shock on new loan terms

Note: This figure shows the results of estimating equation 3.2, replacing credit growth with loan terms on new loans. Period: 2019Q4-2023Q4. Source: Credit register, ENERGI, FIRE, FIRM and own calculations.

though not significantly. However, loan maturities fell significantly and already from the first quarter of 2022. These findings suggest that banks reduced credit supply for high-energy-intensive firms vis-a-vis low-energy-intensive firms. The effects are short-lived, lasting mainly for the second and third quarters of 2022 before returning to pre-shock levels.

6.2 Higher interest rate spreads at the loan level

One potential concern with the firm-level regressions is that they mask composition effects from different loan choices at different points in time. If firms, for example, reduce mortgage borrowing (with low interest rates) by less than credit line borrowing (with high interest rates), this would be picked up as a fall in interest rates. To estimate the effect of the energy price shock on interest rates that accounts for such composition effects, we estimate the following regression at the loan level:

$$\begin{aligned} r^m_{lfbt} - r^m_t = \alpha + \sum_{\tau=T_1}^{T_2} \beta_\tau \left(1_{\bar{EI}(f)=high} \times 1_{t=\tau}\right) \\ + \delta_{maturity(l)} + \delta_{instrument(l)} + \delta_{collateralized(l)} \\ + \delta_f + \delta_{risk(f,t)} + \delta_{bt} + \varepsilon_{lfbt}. \end{aligned} \tag{6.1}$$

r^m_{lfbt} is the interest rate of loan l from firm f at bank b issued at time t with maturity m. r^m_t is a reference rate with the same maturity. $1_{\bar{EI}(f)=high}1_{t=\tau}$ is a set of interacted time $\times$ high energy intensity dummies. $\delta_{maturity(l)}$, $\delta_{instrument(l)}$, and $\delta_{collateralized(l)}$ are, respectively, dummies for the maturity of a loan, the type of loan and whether a loan is collateralized. These fixed effects control for loan characteristics. δ_f are firm fixed effect, $\delta_{risk(f,t)}$ are fixed effects for 10 bins of firm risk. These fixed effects control flexibly for borrower risk. δ_{bt} are interacted bank and time fixed effects, controlling for credit supply. The coefficients of interest are the β_τ, which measure the differential response of credit spreads for high-energy intensity firms.

Table 6 displays the results. Controlling for loan type heterogeneity, borrower risk and bank and industry trends, Column 1 shows that credit spreads for new loans of high-energy-intensive firms increased by 1.6 percentage points per year relative to those of low-energy-intensive firms. The effect is significant at the five per cent confidence level. Columns 2 to 6 show that accounting for loan-level characteristics, borrower risk, and bank and industry trends is important.

Table 7 shows that riskier, larger, and younger firms saw a stronger increase in loan spreads. These are exactly the groups that did not see a decline in credit growth, suggesting that these firms had less elastic credit demand but faced a decline in credit supply

Table 6: Loan-level credit spread regressions

Note: This table shows the results of estimating various variants of equation 6.1. It reports the β_{22Q2} coefficients, with t-statistics in parentheses. The dependent variable is the annualized credit spread of the loan over a government bond with the same maturity. Column 1 contains the baseline specification. Column 2 removes bank $\times$ time fixed effects; Column 3 additionally removes industry $\times$ time fixed effects; Column 4 firmly fixed effects; Column 5 firm risk group fixed effects; and Column 6 maturity, instrument type and collateralization controls. In all columns, residuals are clustered at the industry and time level. Estimation sample: 2020Q1-2023Q4.

	(1)	(2)	(3)	(4)	(5)	(6)
High EI $\times$ 22Q2	1.587*	1.355	0.124	0.128	1.083**	2.062***
	(2.41)	(1.84)	(0.35)	(0.31)	(3.35)	(4.79)
Loan controls	Yes	Yes	Yes	Yes	Yes	No
Firm risk group FE	Yes	Yes	Yes	Yes	No	No
Firm FE	Yes	Yes	Yes	No	No	No
Sector $\times$ Time FE	Yes	Yes	No	No	No	No
Bank $\times$ Time FE	Yes	No	No	No	No	No
R2	0.698	0.678	0.570	0.339	0.336	0.00867
Obs.	23083	23107	23852	24185	30699	30699

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

conditions.

7 Conclusion

The energy price shock triggered by the Russian invasion increased the volatility of energy prices and, ultimately, uncertainty for energy-intensive firms. The effects of this shock were significant and persistent, especially for the most energy-intensive firms. Our analysis suggests that the shock caused a sharp decline in credit growth in the quarter following the invasion. This decline resulted mainly from low-risk firms reducing their credit demand for precautionary reasons to increase the distance from their borrowing constraints. However, prudence was not limited to the demand side, as banks also appear to have tightened the supply of new loans to high-risk firms by charging higher interest rate spreads.

Future energy markets will experience periods of large fluctuations in energy prices. In this context, our results highlight the importance of understanding financial frictions on both the credit demand and credit supply sides in order to assess the impact of such fluctuations.

Our results open up new possibilities for future research. For instance, researchers could investigate the real effects of energy price shocks, bearing in mind that financial con-

Table 7: Heterogeneous effects on loan spreads

Note: This table shows the results of estimating various variants of equation 6.1. It reports the β_{22Q2} coefficients, with t-statistics in parentheses. The dependent variable is the annualized credit spread of the loan over a government bond with the same maturity. Column 1 splits firms at the median by the share of debt maturing in the second quarter of 2022. Column 2 splits firms according to their ex-ante bank-reported default probability at the 75th percentile. Column 3 splits firms according to their number of employees, with firms with less than 90 employees classified as small and firms with more than 90 employees classified as large. Column 4 splits firms according to age, with firms aged 20+ years classified as old. Column 5 splits firms according to the median ratio of current assets, excluding inventories and current liabilities in 2021. In all columns, residuals are clustered at the industry and time level. Estimation sample: 2020Q1-2023Q4.

	(1) Maturity	(2) Riskiness	(3) Size	(4) Age	(5) Liquidity
22Q2 × high maturity	0.0696				
	(0.08)				
High EI × 22Q2 × low maturity	0.908				
	(0.98)				
High EI × 22Q2 × high maturity	2.166				
	(1.87)				
22Q2 × high def. risk		0.321			
		(0.39)			
High EI × 22Q2 × low def. risk		0.968			
		(0.99)			
High EI × 22Q2 × high def. risk		2.881*			
		(2.60)			
22Q2 × large firm			-1.868		
			(-1.66)		
High EI × 22Q2 × small firm			0.369		
			(0.43)		
High EI × 22Q2 × large firm			2.522*		
			(2.79)		
22Q2 × old firm				1.570	
				(1.83)	
High EI × 22Q2 × young firm				4.107**	
				(3.04)	
High EI × 22Q2 × old firm				1.039	
				(1.56)	
22Q2 × high liquidity					0.689
					(0.80)
High EI × 22Q2 × low liquidity					2.429
					(1.36)
High EI × 22Q2 × high liquidity					1.516
					(1.76)
Firm FE	Yes	Yes	Yes	Yes	Yes
Sector × Time FE	Yes	Yes	Yes	Yes	Yes
Bank × Time FE	Yes	Yes	Yes	Yes	Yes
R2	0.691	0.700	0.699	0.699	0.698
Obs.	22800	23083	23083	23083	23075
F-test $\beta^1 = \beta^2$	0.645	1.827	3.582	5.894	0.181
p-value	0.433	0.194	0.0755	0.0266	0.676
F-test $\beta^2 + \gamma = 0$	3.530	7.434	0.334	6.136	3.957
p-value	0.0775	0.0144	0.571	0.0241	0.0630

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

ditions likely play a key role in shaping their impact. Further, researchers could study the heterogeneous impact of energy price shocks on different economies, accounting for differences in energy efficiency and industry composition across countries.

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Appendix

A Descriptive Statistics

This section reports summary statistics for the firm-level dataset and the firm-bank-level dataset.

A.1 Sample Selection

Table 8: Comparing the ENERGI sample to the universe of firms.

Note: This table reports summary statistics for the firms included in the energy use survey. The data are annual for the years 2012-2021. The first column reports statistics for the universe of Danish firms. The second column reports statistics for firms with at least 20 employees. The third column reports statistics for the subsample included in the energy use survey. Industry classifications are based on the Danish DB07 classification at the 10-group level. Size and age groupings follow Clymo and Rozsypal (2022).

	All firms mean	$\geq$20 employees mean	ENERGI sample mean
Sectors			
Manufacturing & Mining	8.0	17.2	90.4
Trade & Transportation	31.6	28.4	6.0
Other	60.4	54.4	3.6
# Employees			
0-30	94.1	35.0	39.6
31-60	3.0	32.5	27.1
61-90	1.0	10.8	10.9
90+	1.8	19.9	22.3
Age (Years)			
0-3	18.7	6.1	5.5
4-8	20.2	13.0	9.4
9-19	30.1	30.7	25.3
20+	30.8	48.6	59.9
Observations	1,284,273	117,035	25,091
Unique firms	253,754	19,061	2,880
# obs/firm	5	6	9

The energy consumption survey is based on manufacturing firms with establishments with at least 20 employees. How relevant is this sample when compared to the full population of firms? Table 8 shows how the ENERGI sample differs from the full population of Danish firms.[19] There are 253,754 firms in the full sample. Of these, 19,061 have more than 20

19. We focus on active firms with at least one employee besides the owner.

employees, and 2,880 are in the ENERGI sample. Eight per cent of firms in Denmark are manufacturing firms. Most firms in the population are small, with 94.1 per cent having fewer than 30 employees. The sample of firms with more than 20 employees has similar firm demographics compared to the ENERGI sample, which contains primarily manufacturing firms. The total employment of firms in the ENERGI sample is 226,000 full-time equivalent positions. For comparison, the Danish manufacturing sector in 2021 had a total employment of 298,908 full-time equivalent positions.

A.2 Firm-Level Summary Statistics

Table 9: Summary statistics at the firm level

Note: This table reports summary statistics for the merged dataset with firm accounting data and energy use data. It reports means, with standard deviations in parentheses. The unit of observation is a firm-year. The last column reports summary statistics for the full sample. The first five columns report summary statistics for firms grouped according to their revenue-based energy intensity, calculated according to equation 2.2. The accounting data are annual for 2012-2022; the energy use data is bi-annual for 2012-2022. Source: ENERGI, FIRE, FIRM and own calculations.

	0%-25% mean/sd	25%-50% mean/sd	50%-75% mean/sd	75%-95% mean/sd	95%-100% mean/sd	all mean/sd
Overall						
Rev. based energy intensity (%)	0.30	0.93	1.98	4.64	15.50	2.51
	(0.17)	(0.22)	(0.42)	(1.56)	(8.96)	(3.98)
Tech. based energy intensity (GJ/FTE)	47.97	83.39	163.78	607.36	2404.46	297.48
	(579.27)	(91.79)	(537.53)	(1932.86)	(4323.86)	(1396.02)
By type						
Gas & el. intensity (%)	0.23	0.76	1.72	4.04	12.95	2.04
	(0.15)	(0.27)	(0.52)	(1.61)	(7.53)	(3.23)
Gas intensity (%)	0.04	0.13	0.25	0.69	3.98	0.42
	(0.07)	(0.17)	(0.33)	(1.08)	(5.97)	(1.58)
El. intensity (%)	0.19	0.63	1.46	3.34	8.96	1.62
	(0.13)	(0.23)	(0.49)	(1.49)	(5.64)	(2.38)
Other characteristics						
Revenue (Mio. of DKK)	644.69	469.28	299.71	330.76	239.49	374.72
	(3805.97)	(2962.22)	(1966.43)	(1314.22)	(512.83)	(2546.59)
Employment (FTE)	164.09	146.55	110.10	113.92	90.33	139.60
	(647.90)	(635.87)	(319.96)	(222.64)	(102.27)	(987.65)
Age (Years)	25.80	28.35	27.36	29.57	34.51	26.19
	(17.60)	(17.20)	(16.45)	(19.68)	(22.35)	(17.96)
Exports/revenue (%)	45.38	43.33	37.42	39.39	38.62	38.09
	(38.19)	(36.26)	(34.03)	(34.66)	(35.21)	(36.35)
Imports/revenue (%)	20.55	19.12	16.70	19.70	19.17	18.55
	(19.26)	(18.13)	(17.22)	(18.62)	(17.44)	(19.47)
Book leverage (%)	56.15	56.42	58.99	58.51	54.40	58.09
	(21.99)	(21.70)	(20.73)	(22.57)	(23.20)	(22.21)
Capital/employment (Mio. DKK/employee)	0.69	0.61	0.61	0.93	1.56	0.72
	(1.42)	(1.09)	(0.90)	(1.24)	(1.82)	(1.28)
Observations	2834	2834	2834	2267	566	27049

How important is energy consumption for manufacturing firms? Moreover, how do firms with low energy intensity differ from firms with high energy intensity? Table 9 displays summary statistics at the firm level. The last column shows summary statistics for the full sample; the first five columns show summary statistics for firms in different energy intensity bins.

For most firms, energy expenditures only comprise a small share of total revenues. The average energy intensity is around 2.36 per cent of revenue. Most energy expenditure comes from gas and electricity, which make up 2 per cent of revenue. The average firm has 140 employees.

However, there is substantial variation in energy intensity across firms. In particular, although energy expenditures are only 2.5 per cent of revenue for the average firm, for the top five per cent of energy-intensive firms, energy expenditures make up 15.5 per cent of revenue. The firms with the highest energy intensity are smaller, as measured by revenue or employment. They are also older, less likely to export, and more capital-intensive than firms with low energy intensity. It is, therefore, important to be able to control for all these characteristics in the subsequent analysis.

A.3 Firm-Bank Level Summary Statistics

Table 10 displays summary statistics from the credit register at the bank × firm × quarter level. The full dataset has 2.2 million observations. There are 230,000 firms and 32 banks. For comparison, in 2021, there were 328,445 firms and 94 banks in Denmark. In the matched dataset, there are 1,801 firms and 26 banks.

The average firm-bank relationship in the matched sample has 29 million DKK of outstanding debt, with an interest rate of, on average, 2.3 per cent and a maturity of 5.8 years. Before the energy price shock (2019Q4-2021Q2), the average firm borrowed an additional 7 million DKK from each of its banks at an interest rate of 4.1 per cent, with a maturity of 3.8 years. The average firm in the matched dataset borrows more at lower interest rates and lower maturities than the average firm in the full dataset. The firms' delinquency probability in the merged dataset is lower than in the full dataset.

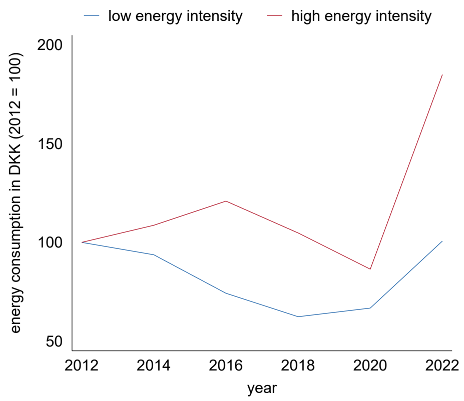
The last two columns compare firms with energy intensity below the median (3rd column) and above the median (4th column). Firms with energy intensity below the median borrow more against collateral and have lower default rates, but they are otherwise quite similar to firms with energy intensity above the median.

Table 10: Summary statistics from the credit register before the energy crisis.

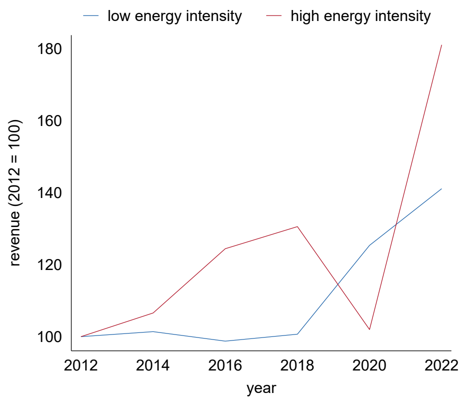
Note: This table reports summary statistics for the merged dataset, including credit register data, firm accounting data and energy use data. It reports means, with standard deviations in parentheses. The data is at the bank × firm × quarter level. The credit register data is quarterly. The period is 2019Q4-2021Q3. The first column reports summary statistics for the universe of loans from banks to firms in the credit register. The second column reports summary statistics for the matched dataset. The third and fourth columns split observations into low and high energy intensity firms at the median of 2012-2020 average revenue-based energy intensity, calculated according to equation 2.2. Source: Credit register, ENERGI, FIRM, FIRE and own calculations.

	Full dataset mean/sd	Matched dataset mean/sd	Low EI mean/sd	High EI mean/sd
Outstanding loans				
Amount (1000s of DKK)	16251.39	41854.16	28718.22	17997.32
	(2.1e+06)	(5.3e+05)	(1.7e+05)	(80487.10)
Interest (% p.a.)	4.62	2.27	2.30	2.22
	(5.71)	(2.91)	(3.01)	(2.80)
Maturity (Years)	11.87	5.78	5.59	5.93
	(9.55)	(5.76)	(5.84)	(5.63)
% collateralized	26.49	24.60	28.20	20.43
	(43.75)	(41.76)	(43.70)	(39.00)
% of debt in credit register	39.43	33.92	28.58	39.36
	(36.64)	(29.69)	(28.44)	(30.11)
New loans				
Amount (1000s of DKK)	2143.29	7212.75	5182.52	1954.56
	(1.7e+05)	(2.2e+05)	(73307.18)	(34003.48)
Interest (% p.a.)	10.08	4.13	4.43	3.91
	(9.45)	(6.43)	(6.75)	(6.14)
Maturity (Years)	8.08	3.82	3.68	3.91
	(9.46)	(4.38)	(4.20)	(4.37)
% collateralized	45.54	17.92	20.09	15.03
	(49.73)	(38.06)	(39.77)	(35.48)
Shares, outstanding loans				
% trade credit	0.04	0.80	1.10	0.59
	(1.85)	(8.71)	(10.29)	(7.31)
% mortgages	36.00	21.13	18.28	24.38
	(47.99)	(40.82)	(38.65)	(42.94)
% credit lines	31.63	28.50	30.69	26.59
	(45.73)	(42.76)	(43.82)	(41.69)
% C&I loans	16.79	13.24	13.29	13.54
	(36.44)	(31.36)	(31.52)	(31.55)
% leasing	8.54	22.66	20.00	25.21
	(27.41)	(39.91)	(38.22)	(41.27)
% credit cards	6.80	12.91	16.64	9.63
	(24.87)	(32.80)	(36.41)	(28.85)
Delinquency				
Default probability (% p.a.)	6.06	4.11	3.45	4.82
	(18.49)	(15.69)	(13.91)	(17.33)
Observations	1,308,345	27,856	12,986	13,179
Unique firms	245,563	2,323	1,129	1,045
Unique banks	32	29	25	27

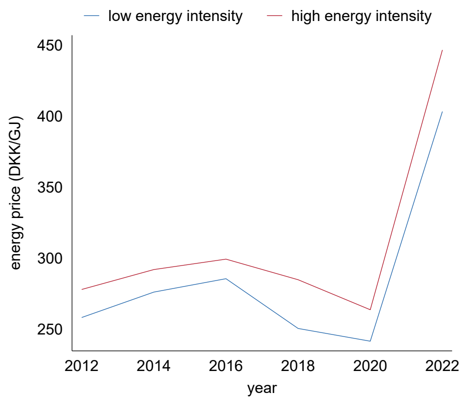
(a) Energy cons. value (index, 2012=100)



(b) Revenue (index, 2012=100)



(c) Energy price (DKK/GJ)



(d) Energy cons. quantity (1000s of GJ)

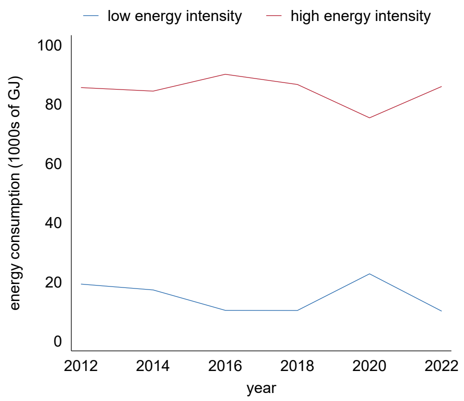


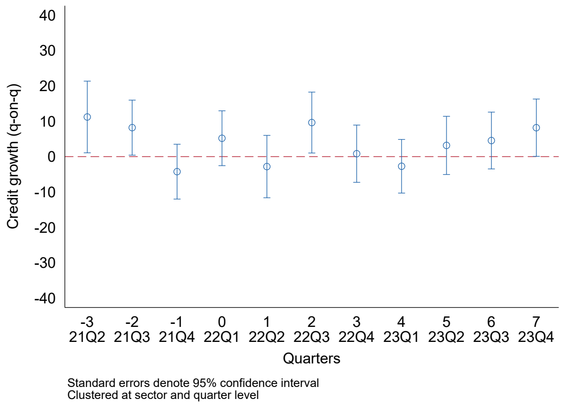
Figure 9: Dynamics of average energy intensity, prices and consumption, low-energy-intensity vs high-energy-intensity firms.

Note: Panel 9a shows the numerator of the energy intensity time series displayed in Figure 2, energy consumption, Panel 9b their denominator, revenue. Panels 9c and 9d further decompose the numerator into the average energy price and the average energy quantity.

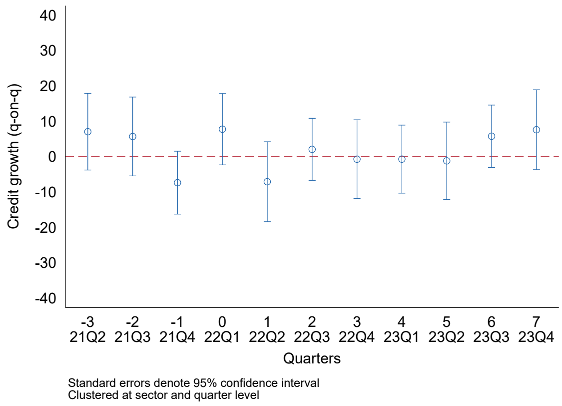
A.4 Decomposing the increase in energy intensity

B Robustness

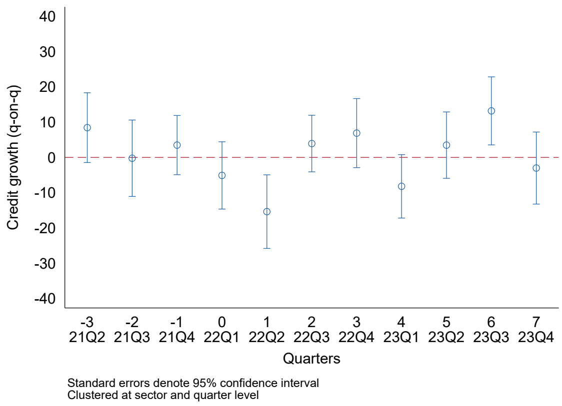
B.1 Alternative Quantile Specifications



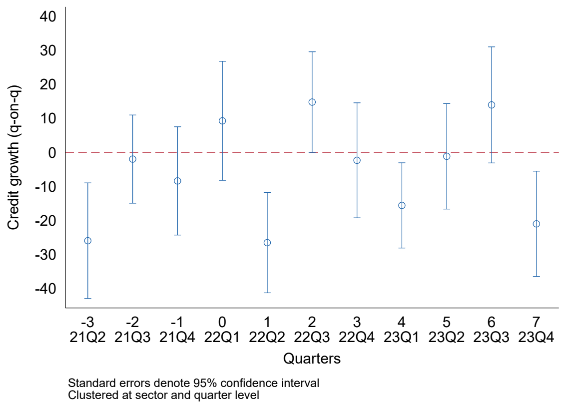
(a) 25% – 50%



(b) 50% – 75%



(c) 75% – 95%



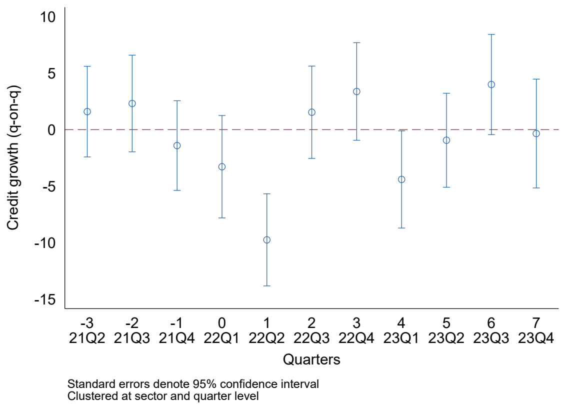
(d) 95% – 100%

Figure 10: Effects on credit growth for different energy intensity quantiles

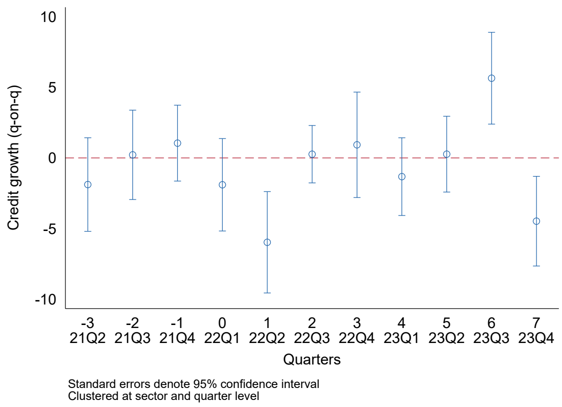
Note: This figure shows the results of estimating a variant of equation 3.2 with multiple energy intensity quantiles. Period: 2019Q4-2023Q4. Source: Credit register, ENERGI, FIRE, FIRM and own calculations.

B.2 Robustness Checks for the Main Specification

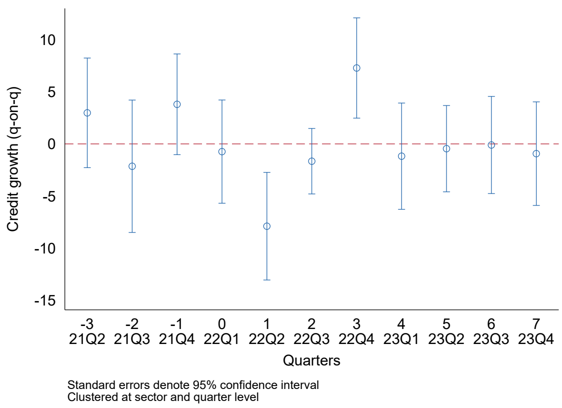
Figures 11 and 12 show that the main result is robust to different changes in specification. Panel 11a replaces the energy intensity dummies with dummies that measure energy intensity differences within an industry. We obtained similar results to those of the baseline. Panel 11b with a continuous measure of energy intensity, where we replace the energy intensity dummy with the logarithm of revenue-based energy intensity, standardized to



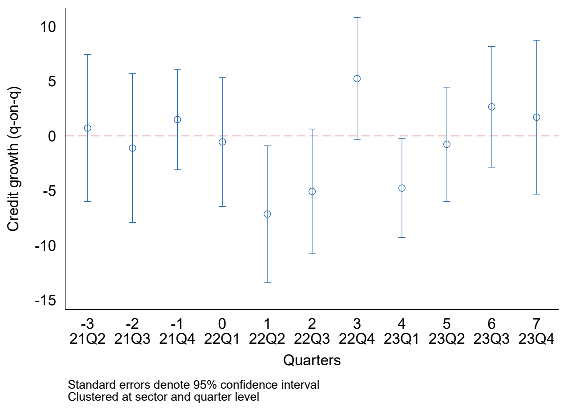
(a) Within industry measure of EI



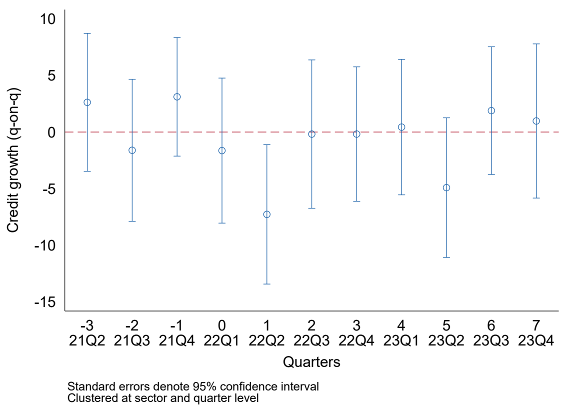
(b) Continuous measure of EI



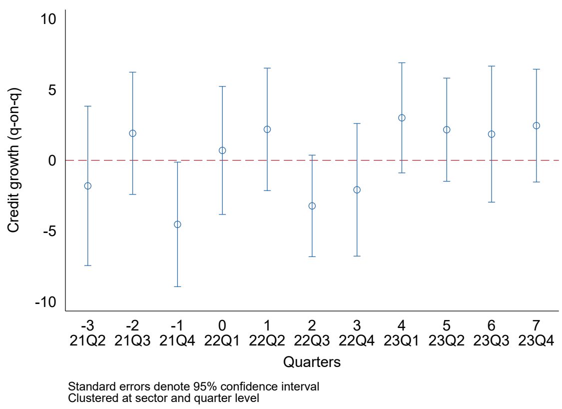
(c) Tech measure of EI



(d) Only gas & electricity



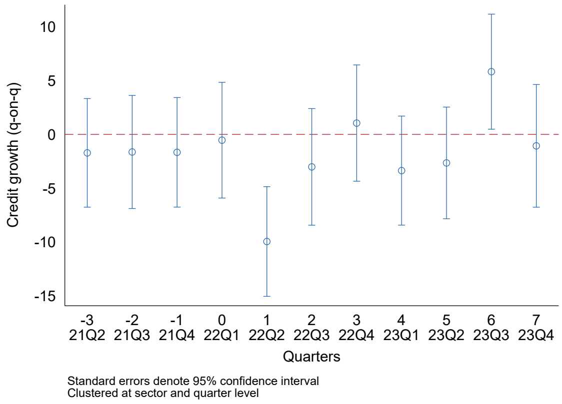
(e) Only electricity



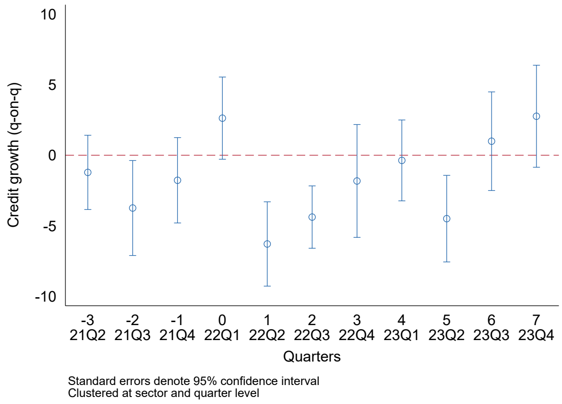
(f) Only gas

Figure 11: Various robustness checks – 1

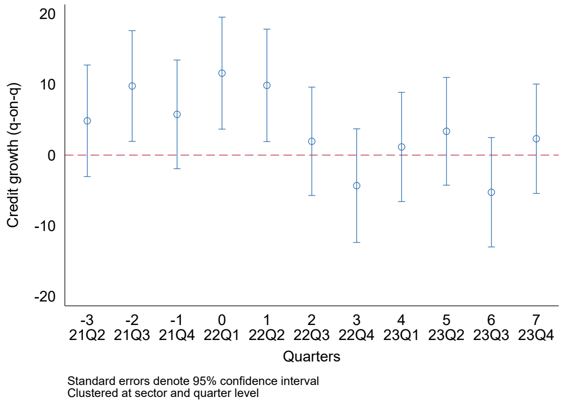
Note: This figure shows various variations of estimating equation 3.2. Period: 2019Q4-2023Q4. Source: Credit register, ENERGI, FIRE, FIRM and own calculations.



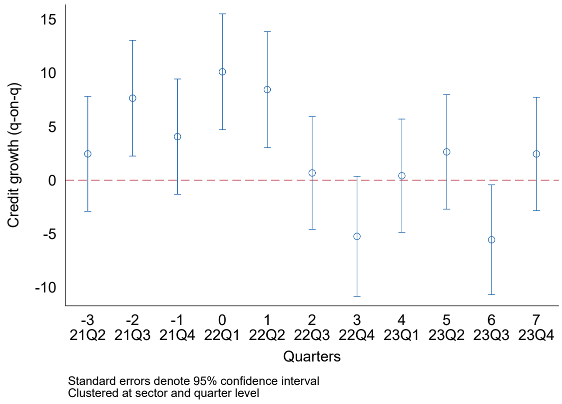
(a) No bank × time fixed effects



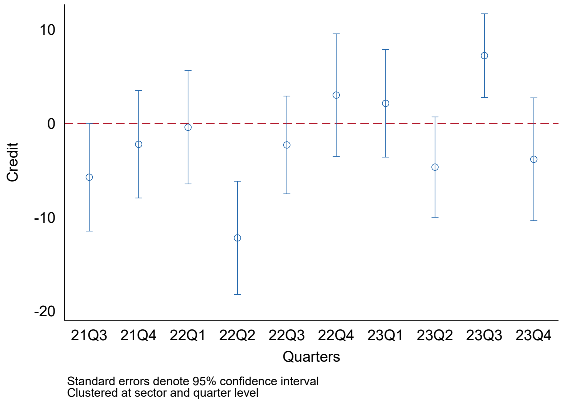
(b) No industry × time fixed effects



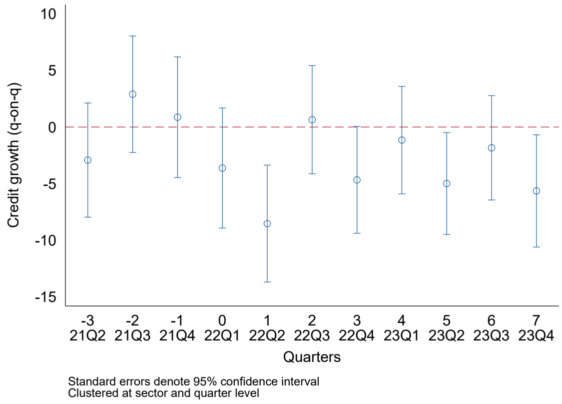
(c) Only firm fixed effects



(d) No fixed effects



(e) Firm-level regression



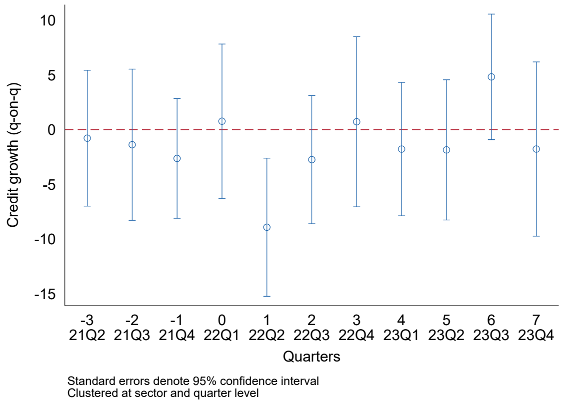
(f) Change in energy intensity

Figure 12: Various robustness checks – 2

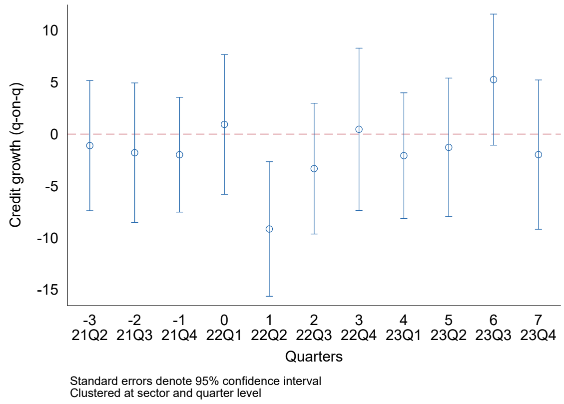
Note: This figure shows various variations of estimating equation 3.2. Period: 2019Q4-2023Q4. Source: Credit register, ENERGI, FIRE, FIRM and own calculations.

have mean zero and variance one. Results are similar to Figure 4. Panel 11c shows results with the tech-based measure of energy intensity. This measure works less well, and results become noisier than in the baseline. Panel 11d shows results with a measure of energy intensity that only includes gas and electricity. Results are again similar to Figure 4. Panel 11e shows results for electricity only. There is a stronger pre-trend, and the recovery after 2022Q2 is less pronounced. Panel 12a removes bank × time fixed effects, showing that they are not crucial for the results. Panel 12b removes industry × time fixed effects, showing that these matter considerably. Panel 12e estimates a specification at the firm level instead of at the firm-bank level.

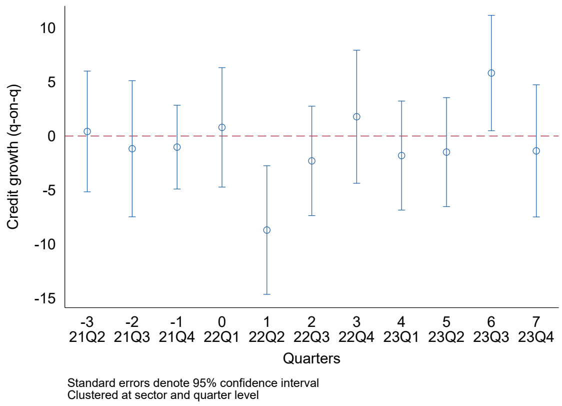
B.3 Horse Race Regressions



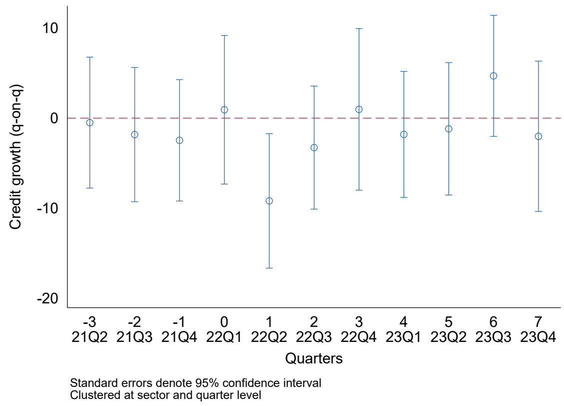
(a) Energy intensity vs age



(b) Energy intensity vs size



(c) Energy intensity vs leverage



(d) Energy intensity vs age, size & leverage

Figure 13: Controlling for other firm characteristics

Note: This figure shows the results of estimating equation 3.2, adding an interaction between energy intensity, time fixed effects, and one-quarter lagged firm characteristics quantiles. Period: 2019Q4-2023Q4. Source: Credit register, ENERGI, FIRE, FIRM and own calculations.

Table 11: Controlling for other firm characteristics

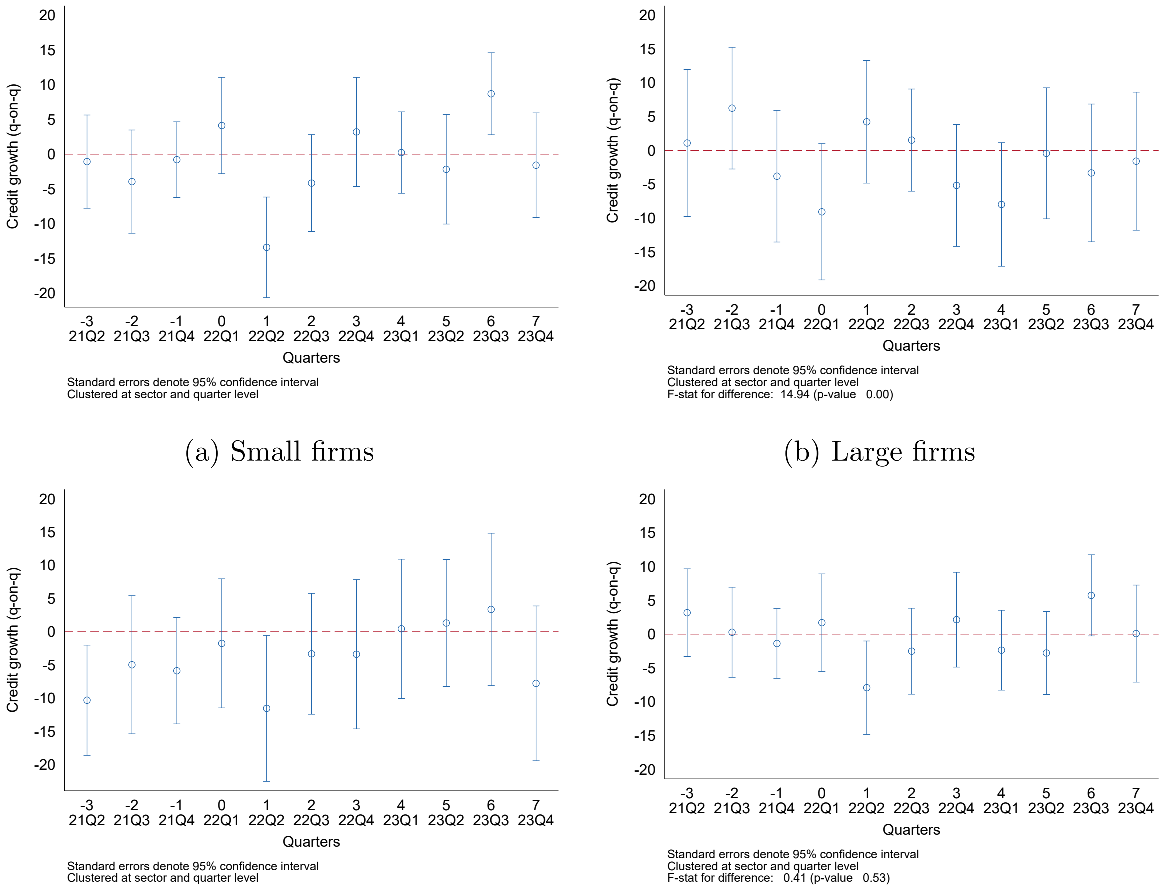
Note: This table shows results of estimating alternative versions of equation 3.2. It reports the β_{2022Q2} and γ_{2022Q2} coefficients, with t-statistics in parentheses. The dependent variable is credit growth, as defined in equation 2.1. All specifications include firm fixed effects, four-digit industry $\times$ time fixed effects and bank $\times$ time fixed effects. Column 1 reports the baseline. Column 2 splits firms according to their number of employees. Column 3 splits firms according to age. Column 4 splits firms according to the median leverage ratio, computed as book debt divided by book assets, in 2021. Column 5 includes all firm controls. In all columns, residuals are clustered at the industry and time level. Estimation sample: 2020Q1-2023Q4.

	(1) Baseline	(2) Size	(3) Age	(4) Leverage	(5) All
High EI $\times$ 22Q2	-8.753**	-9.151**	-8.917**	-8.696**	-9.194*
	(-3.18)	(-3.01)	(-3.01)	(-3.12)	(-2.62)
22Q2 $\times$ 31-60 employees		10.31**			10.80*
		(3.49)			(2.81)
22Q2 $\times$ 61-90 employees		10.09*			10.25*
		(2.49)			(2.18)
22Q2 $\times$ >90 employees		2.422			2.033
		(0.52)			(0.37)
22Q2 $\times$ 3-8 years			18.75		17.74
			(2.08)		(1.85)
22Q2 $\times$ 8-19 years			19.37		18.23
			(1.89)		(1.75)
22Q2 $\times \geq$ 20 years			21.11		18.04
			(2.06)		(1.74)
22Q2 $\times$ high leverage				-9.841***	-9.888**
				(-5.18)	(-3.40)
Firm FE	Yes	Yes	Yes	Yes	Yes
Sector $\times$ Time FE	Yes	Yes	Yes	Yes	Yes
Bank $\times$ Time FE	Yes	Yes	Yes	Yes	Yes
R2	0.129	0.130	0.131	0.129	0.131
Obs.	43281	43281	43281	43184	43184

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

C Additional Results



(a) Small firms

(b) Large firms

(c) Young firms

(d) Old firms

Figure 14: Effects of the energy price shock on the credit growth of different types of firms – II

Note: This figure shows the results of estimating equation 5.6. Period: 2019Q4-2023Q4. Source: Credit register, ENERGI, FIRE, FIRM and own calculations.

C.1 Larger Effect for Smaller Firms

Heterogeneity in effect by firm size could arise because small firms are more exposed to aggregate fluctuations (Crouzet and Mehrotra 2020; Clymo and Rozsypal 2022), because smaller firms face higher default risk (Begenau and Salomao 2019) or because small firms have less bargaining power than large firms vis-a-vis their lenders (Chodorow-Reich 2014; Chodorow-Reich et al. 2022). Therefore, we expect small firms to have a larger decline in credit growth than large firms.

Column 3 of Table 5 and Panels 14a and 14b show this to be the case indeed. The effect of the energy price shock is larger for small firms than for large firms, relative to low-energy-intensity firms within the same group. This is also true when comparing effects across groups. Equality of treatment effects is strongly rejected. This evidence aligns with smaller firms being closer to their financial constraints and, therefore, having a stronger precautionary motive.

C.2 Larger Effect for Younger Firms

Differences in exposure to shocks over the firm life cycle could lead to age differences in response to the energy price shock (Haltiwanger, Jarmin, and Miranda 2013; Adelino, Ma, and Robinson 2017). Alternatively, it could also be that young firms use older, less energy-efficient capital (Ma, Murfin, and Pratt 2022). We expect that younger firms will respond more to the shock in energy prices.

Column 4 of Table 5 and Panels 14c and 14d show that this is indeed the case. However, the coefficient for young firms is less precisely estimated. This could be because young firms face more volatile credit growth than old firms, consistent with models in which young firms are more exposed to financial frictions than old firms (Kochen 2022). As a result, the two coefficients are not statistically significantly different.

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