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Niels Framroze Møller, Johannes Poeschl

The effects of a large energy price shock on bank credit

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Abstract

This study investigates the effect of the large shock to energy prices following the Russian invasion of Ukraine on bank credit to firms. To isolate the causal effect of the shock, it compares bank lending to high-energy-intensive firms to that of similar low-energy-intensive firms. Following the shock, bank credit to high-energy-intensive firms persistently declined, while their interest rates on new loans rose and other loan terms tightened. Across the distribution, safer firms reduced outstanding credit lines and paid unchanged interest rates on new bank loans, while riskier firms borrowed at higher interest rates.

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

JEL Classification: G21, G32, Q43

Non-Technical Summary

This paper examines how the surge in energy prices following Russia's invasion of Ukraine affected bank lending to firms, using Denmark as a case study. It is relevant for the euro area and central banks because it shows how a sudden increase in production costs can interact with credit markets and influence the transmission of monetary policy.

The authors focus on Danish manufacturing firms, many of which rely heavily on electricity and gas. They combine three main data sources at the firm level: (i) a detailed survey of energy use by all manufacturing plants with more than 20 employees, (ii) the Danish credit register, which records all loans and credit lines between firms and banks on a quarterly basis, and (iii) firms' balance sheet and income statement data. The sample spans several years before and after the invasion of Ukraine, with particular attention to developments from early 2022 onward. This allows the authors to measure each firm's "energy intensity" (the share of energy in its costs) and to track how much it borrows and on what terms.

The empirical approach is based on comparing firms that are similar in many respects but differ in how strongly they are exposed to energy costs. When energy prices rise, highly energy intensive firms are hit harder than firms with low energy use, even if they operate in the same industry and borrow from the same banks. By following bank credit to both groups before and after the energy price surge, the authors infer the impact of the shock.

The paper finds that total bank credit to the Danish manufacturing sector continued to grow after the energy shock, but lending to highly energy intensive firms grew much more slowly than lending to less exposed firms. In the first full quarter after the invasion (second quarter of 2022), the growth rate of bank credit to high energy intensity firms was almost nine percentage points lower than for low energy intensity firms within the same sector and bank. This gap persisted for several quarters and closed only around the third quarter of 2023. This implies that the energy price shock acted as an additional tightening force for the most exposed firms, of a magnitude comparable to the effect of a moderate policy rate increase found in other studies.

The composition of the decline in credit points mainly to a reduction in firms' demand for bank funding. Most of the shortfall comes from lower use of existing credit lines rather than from outright cuts in credit limits imposed by banks. Short term instruments such as credit cards show similar patterns. The effect is strongest among firms that appeared relatively safe borrowers before the shock. These facts suggest that energy intensive firms scaled back their borrowing and possibly postponed or canceled investment projects, likely due to higher uncertainty and weaker expected profitability, instead of relying more heavily on bank credit to finance higher energy bills.

At the same time, the conditions on new loans indicate a change on the supply side. After the shock, energy intensive firms that obtained new bank loans faced higher interest rates, shorter maturities and somewhat stricter collateral requirements than comparable low energy intensity firms. These differences remain even after controlling for usual indicators of firm risk, implying that banks started to price "energy related risk" specifically. This points to a reduction in banks' risk appetite for lending to highly energy dependent firms, even though there was no generalised credit crunch.

For the ECB and other central banks, the Danish experience illustrates how large input cost shocks can reshape the allocation of credit across firms. Even when aggregate credit remains stable, firms with high exposure to the shock may experience an effective tightening of financing conditions, both because they borrow less and because banks become more cautious in lending to them. This affects the transmission of monetary policy and can create pockets of vulnerability in sectors that are both energy intensive and bank dependent. Monitoring firms' energy exposures and banks' sectoral concentrations can therefore improve the assessment of how similar shocks would play out in the euro area and inform both monetary policy analysis and financial stability surveillance.

1 Introduction

The large energy price increase in the wake of the Russian invasion of Ukraine has put shocks to energy prices into the spotlight of academics and policymakers. While a recent literature studies the effects of predictable changes to energy prices, for example because of changes in environmental regulation (e.g., Altavilla, Boucinha, Pagano, and Polo (2024), Antoniou, Delis, Ongena, and Tsoumas (2024), Correa, He, Herpfer, and Lel (2022), and Ivanov, Kruttli, and Watugala (2024)), there is, to the best of our knowledge, little empirical evidence on the effects of energy price *shocks*, i.e., large, unanticipated changes to energy prices, on bank credit to firms. Such evidence is important in order to understand the implications of energy price shocks for monetary transmission and financial stability.

This paper provides 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. By comparing bank credit of high-energy-intensive firms to that of similar low-energy-intensive firms, and including bank-time and sector-time fixed effects, we argue that we can isolate the shock on bank credit as the difference between firms that differ in their exposure to the energy price shock, but are likely to be similarly exposed to other coinciding shocks.

We find that while credit growth to the manufacturing sector overall increased following the energy price shock, credit growth of high-energy-intensity firms increased by 8.75 percentage points less relative to that of low-energy-intensity firms in the quarter after the shock. To put this number into perspective, we provide a back-of-the-envelope calculation, suggesting that the aggregate level of credit to the manufacturing sector would have increased by around 5.5 percent more if energy-intensive firms had borrowed as much as low-energy-intensive firms. As the decline in credit growth was most pronounced for less risky firms and concentrated in their utilization of outstanding credit lines, we argue that these results point to a relative decline in credit demand. However, we also find that interest rates on new loans rose, even when controlling for firm risk, suggesting that a decline in banks' risk appetite also played a role in the propagation of the energy price shock.

Overview of the Paper Sections 2 and 3 discuss the energy price shock, its impact on the Danish economy and possible transmission channels to bank lending derived from the the theoretical literature. We show that the energy price shock was a large, unanticipated, and broad-based shock to firms' energy expenditure. Based on the theoretical literature, we argue that two channels mainly operating through credit supply, namely the credit risk channel and the risk taking channel, and three channels mainly operating through credit demand, namely the working capital channel, the investment channel and the precautionary savings channel, could be at play. These channels yield different predictions about the sign of the response of credit quantities, as well as about which credit types and which firms will primarily respond to the energy price shock.

To identify the causal effect of the energy price shock on firm credit, we use a difference-in-differences approach. The main identification challenge is that the Russian invasion of Ukraine created many other, confounding shocks, like an increase in geopolitical risk, a decline in consumer confidence, or supply chain disruptions. These could confound the true, causal effect of the energy price shock. Our approach to overcome this challenge is to compare the credit growth of firms that differ in energy intensity and thereby in their exposure to the energy price shock but are otherwise similarly exposed to other confounding shocks. To control for exposure to other shocks, we include in our baseline granular industry-time and bank-time fixed effects, and in robustness checks size-time, age-time, and leverage-time fixed effects. 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.

Our analysis is data-intensive, as it requires information on firms' energy use, their bank loans, and a broad set of firm characteristics. We therefore create a new dataset using a confidential credit register from the Danish Central Bank, a survey run by Statistics Denmark, and various administrative data registers. 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, and with data on firm balance sheets. We obtain a unique dataset that allows us to trace out the impact of the shock at business cycle frequencies.

We establish four main results. First, 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. Economically, the response of credit is comparable in size to its response to a half-point rise in the short-term interest rate as reported in Jiménez, Ongena, Peydró, and Saurina (2014).

Second, guided by the theoretical predictions, 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. In unreported results, we find that the bulk of this decline comes from utilization of credit lines, not changes in credit limits. This exercise suggests an important role for credit demand in driving the decline in credit.

Third, we analyze the effects of the shock on loan terms of new loans (i.e. loans issued in the current quarter). 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.[1] 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. We find that the interest rate spread for energy-intensive firms rose, even when controlling for firm risk.

Fourth, 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. We find that the decline in credit growth because of the energy price shock is more pronounced for less risky firms and firms with higher cash balances, in line with V. V. Acharya, Almeida, and Campello (2013). Those are all firms that one would expect to be less credit-constrained. Moreover, the interest rate spread on new loans rose but only for more risky firms. This suggests that over and above the credit risk channel the risk premium channel may have increased the cost of bank lending for firms.

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. We address this challenge in multiple ways. First, we do not find pre-shock heterogeneity in trends. Second, we use an alternative definition of energy intensity that relies on within-sector heterogeneity instead of across-sector heterogeneity. Third, we introduce the random timing of energy contract resets as an additional source of variation by looking at the change instead of the level of energy expenditure during 2022. Fourth, we control for interactions between time dummies and another salient firm characteristics, like size, age, or leverage. In all of these exercises, the main result remains unchanged.

Literature This paper contributes to the literature on the effects of an increase in energy prices on the financial decisions of firms and banks. Our main contribution is to investigate the impact of an episode where energy prices rose unanticipatedly and for arguably exogenous reasons. The closest paper to this one is Ivanov et al. (2024), which analyzes the effect of the Californian cap and trade policy for CO2 emissions on credit supply, finding a negative effect on bank lending and credit conditions. Altavilla et al. (2024) find, in the cross-section of firms, a negative association between firms' emissions and bank lending. Antoniou et al. (2024) show that the (anticipated) decline in the price of pollution permits following the introduction

1. 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.

of the second state of the European cap-and-trade system led to a decline in financing costs for polluting firms. Delis, Greiff, Iosifidi, and Ongena (2024), Javadi and Masum (2021) and Kacperczyk and Peydro (2021) also find credit supply effects for firms with higher climate risk exposures. These papers are primarily concerned with understanding the effects of persistent and anticipated increases in energy prices, for example because of changes in regulation. Instead, we analyze a different type of an unanticipated and transitory shock and, in addition, investigate credit demand channels, showing that those 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 firms. 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 bank credit to firms.

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. Gelain and Lorusso (2025) study the effects of oil shocks on US banks, showing that such shocks reduce credit supply. Alessandri and Gazzani (2025) 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; Giroud and Mueller 2017). To our knowledge, no paper studies the effects of energy price shocks on bank lending to different firms.

2 Background: The Energy Price Shock of 2022

We use data from Denmark. The Danish data are uniquely suited for our study, as they combine information from a credit register with data on firms' energy use and their balance sheets. This dataset allows us to use within-sector variation in energy intensity to identify the effect of the energy price shock, and to control for firm characteristics that proxy exposure to other confounding shocks.

Beyond the rich data, studying the effects of the energy price shock in the Danish context is useful for a broader understanding of its impact in developed economies, as Denmark is a highly developed economy with a manufacturing sector and a banking sector that are similar to and closely integrated with those of its neighboring countries. If anything, according to data from the International Energy Agency, the Danish manufacturing sector is less energy-intensive than that of many other European countries (International Energy Agency 2023), such that our results likely provide a lower bound on the effect of an energy price shock.

Denmark is an energy-importing country: in 2023, Denmark imported around half of its total energy consumption. Because gas is the marginal source of electricity generation in Denmark when excess electricity demand is high, electricity prices and gas prices tend to co-move strongly (Branner and Ingholt 2023). Even prior to the Russian invasion of Ukraine, Danish firms relied relatively little on direct imports of Russian gas (Di Bella, Flanagan, Foda, Maslova, Pienkowski, Stuermer, and Toscani 2024). However, as European energy markets are well integrated, Danish energy prices tend to evolve similarly as those in the rest of Europe.

The energy price shock following the Russian invasion of Ukraine is of considerable interest for two reasons. First, it was largely unforeseen and driven by international developments. Figure 1 shows the development of Danish gas and electricity prices in 2022. While gas prices started to rise already in September 2021, they spiked in the first quarter of 2022 after the invasion and once more during the second quarter of 2022 when Russia started to shut off gas supplies to some European countries, including Denmark.[2][3] 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.[4]

Second, it was large. As we observe both quantities and values of energy consumption in our dataset, 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 (35 EUR) to 60 EUR per Gigajoule. The increase in effective energy prices was similar for

2. At the time, the rise in gas prices in 2021 was attributed to a lower gas supply from Russia, but without mentions of an invasion of Ukraine. See Sheppard and Wilson (2021) and Sheppard (2021).

3. The main Danish gas importer from Russia, Ørsted, was shut off from the Russian gas supply in May 2022 after refusing to pay for gas deliveries in roubles. See Ørsted (2022).

4. These price developments were further aggravated by adverse weather conditions, leading to lower electricity production by nuclear and hydroelectric power plants in Europe (Branner and Ingholt 2023).

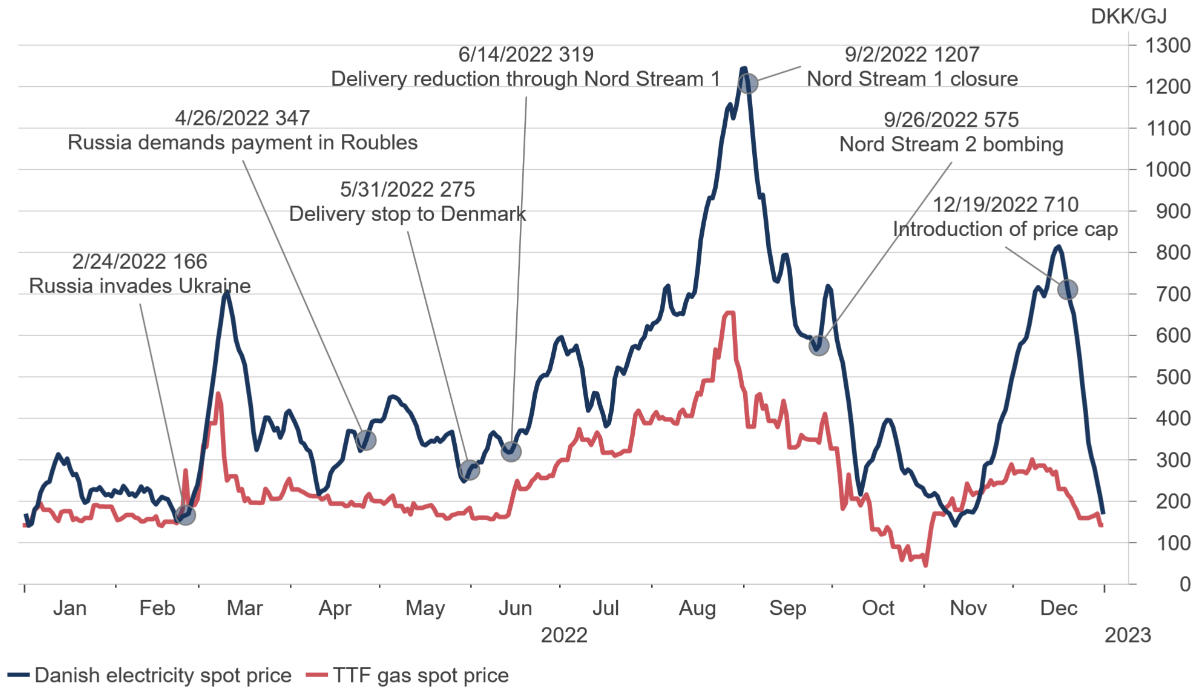


Figure 1: Energy spot market prices and events during 2022

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.

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.

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.[5] It therefore likely played no significant role in explaining our main result about the effect of the energy price shock on firm credit.

3 Theoretical Predictions

The theoretical literature provides multiple channels through which a shock to energy prices could affect bank lending to firms. We distinguish between two channels that operate via the credit supply side, namely the credit risk channel and the risk taking channel, and three channels that operate via the credit demand side, namely the working capital channel, the investment channel and the precautionary savings channel. For each channel, we will state testable hypotheses on its aggregate implications for lending volumes and interest rates, its implications for different types of credit instruments and its implications for different groups of firms.

First, according to the credit risk channel, energy intensive firms could become riskier following an energy price shock (Hackbarth, Miao, and Morellec 2006). For example, as we observe below, cash flows of energy intensive firms declined as their costs increase relative to their revenues. As that raised energy-intensive firms' default risk, banks should have reduced lending or demand higher default compensation from them. We would expect to observe a decline in bank lending volumes and higher lending rates for energy intensive firms. Across credit instruments, the response should be concentrated those more sensitive to default risk, e.g. longer-term loans (He and Milbradt 2016). Across the distribution of firms, we would expect the contraction in credit supply to be most pronounced for ex ante riskier firms, as those typically are more sensitive to macroeconomic risk (Palazzo and Yamarthy 2022).

Second and relatedly, according to the risk-taking channel, banks might have become more risk-averse to energy risk following the energy price shock (Acharya and Naqvi 2012; Dell'Ariccia, Laeven, and Marquez 2014; Jiménez et al. 2014). Consequently, banks' implicit price of energy risk would increase. We would expect an aggregate decline in bank lending and a rise in interest rates for energy intensive firms. But distinct from the credit risk channel, we would expect a rise in loan spreads for energy-intensive firms even when controlling for borrower risk, i.e., a

5. See Bang-Udesen (2022).

higher risk premium for energy risk. Across instruments, we expect the tightening to be more pronounced for instruments more sensitive to firm risk. Across firms, the tightening should be more pronounced for riskier firms.

Third, according to the working capital channel, firms should increase credit demand when their costs rise, as they need more working capital loans to finance operations (Almeida, Carvalho, and Kim 2024). Consequently, their demand for loans should increase, and we would expect an increase in bank lending volumes and higher lending rates. Across instruments, we would expect the increase in demand to be more pronounced for instruments used for liquidity management, like credit lines Sufi (2009). Across the distribution of firms, we would expect a stronger increase in credit for firms with higher energy cost shares, and a stronger increase in credit for firms with a priori less cash (V. Acharya, Almeida, Ippolito, and Perez 2014).

Fourth, according to the investment channel, firms could reduce investment in response to an energy price shock. One reason could be a decline in their growth options, as they might when the firms expect the energy price increase to be persistent (Hayashi 1982; Bernanke 1983). Another reason could be that firms choose to postpone investments because of higher uncertainty (Bloom 2009; Alfaro, Bloom, and Lin 2023). When firms finance their investment at least partly with bank loans, the decline in investment should then lead to a decline in credit demand. Therefore, we would expect a decline in bank lending volumes and in lending rates. Across instruments, this decline should be most pronounced for those types of instruments used to finance investment, like term loans and mortgages. Across the distribution of firms, we would expect a stronger decline in credit demand for firms for which growth options tend to be the most important, e.g., young and small firms (Arnold, Wagner, and Westermann 2013).

Fifth, according to the precautionary savings channel, firms might reduce borrowing for precautionary reasons when faced with higher uncertainty because of volatile energy prices (Bolton, Chen, and Wang 2011; Eisfeldt and Muir 2016). This willingness to accumulate a liquidity buffer could lead firms to accumulate more cash, or, to the extent that they consider credit lines to be a substitute for cash, to draw less on their credit lines. In addition, they might want to draw less on their credit lines to avoid violating covenants, which would allow their lenders to reset the terms of those lines (Chodorow-Reich 2014; Chodorow-Reich and Falato 2022). Consequently, we would expect a decline in credit volumes and a decline in bank lending rates, in particular for credit lines. Across firms, we would expect a stronger decline in credit demand for firms with lower risk and ample financial resources, as these firms have a greater capability of building up precautionary liquidity buffers.

Overall, while the sign of the effect of an energy price shock on bank lending to firms is a priori unclear, the theoretical literature offers guidance on possible transmission channels and provides additional testable implications that can be used to gauge the importance of these transmission channels. We next introduce a dataset that, as we will argue below, will allow us to estimate the causal effect of an energy price shock on bank lending to firms.

4 Identification Strategy

We are interested in estimating the causal effect of the February 2022 shock to energy prices triggered by the Russian invasion of Ukraine 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, a decline in consumer confidence, and sanctions against firms operating in Russia. Moreover, the Danish economy was still recovering from Covid, which also affected macroeconomic and sectoral trends.[6]

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. As we will show below, accounting for sector-time fixed effects is crucial to estimate the causal effect of the energy price shock.

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 of the Danish DB07 industry classification stystem, comprising around 700 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.

The main remaining threat to identification concerns the possible existence of a characteristic that is correlated with a firm's energy intensity as well as its exposure to another, coincident shock. If, for example, larger firms tend to have a higher energy intensity and are at the same time more exposed to geopolitical risk than smaller firms, we would overstate the effect

6. For an alternative approach using aggregate data that relies on constructing a narrative measure of gas supply shocks, see Alessandri and Gazzani (2025).

of the energy price shock. To alleviate this concern, we control for interactions between time fixed effects and salient firm characteristics that might result in differing exposure to coincident shocks across firms.

5 Data

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.

5.1 Energy Use

The data on energy use come from a biannual survey conducted by Statistics Denmark.[7] 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.[8] 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.[9] We aggregate data at the firm level by summing up energy consumption in a given year within a firm across establishments.

5.2 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.

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

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

9. 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.

We clean the data as follows: For maturities, we replace all negative maturities and maturities above 50 years with missing values.[10] For interest rates, we replace all interest rates below -1 per cent and above 50 per cent with missing values. We define *new loans* 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

$$credit\_growth_{fbt} = 100 \times \frac{C_{fbt} - C_{fbt-1}}{0.5\,(C_{fbt} + C_{fbt-1})}, \tag{5.1}$$

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.

5.3 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.

5.4 Defining Exposure to the Energy Price Shock

The main measure of energy intensity measures expenditure as a share of firm revenue.[11] We calculate the revenue-based energy intensity of firm f in year t as

$$EI_{ft} = 100 \times \frac{energy\_dkk_{ft}}{revenue_{ft}}. \tag{5.2}$$

$energy\_dkk_{ft}$ 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

$$\bar{EI}_f = \frac{1}{5} \sum_{t=2012}^{2020} EI_{ft}. \tag{5.3}$$

10. We treat credit lines as having zero maturity.

11. 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 up to 5 observations from 2012 to 2020.

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.

In an alternative model, we further consider a different exposure definition whereby we define firms as exposed when their energy intensity is above the median energy intensity *within* their own industry. This exposure definition sharpens identification, as the treatment and control groups within industries are likely more similar to each other when there is some cross-industry sorting in energy intensities, but comes at the cost of the estimated coefficients being more difficult to interpret.

5.5 Effect of the Shock on Exposed Firms' Energy Intensity

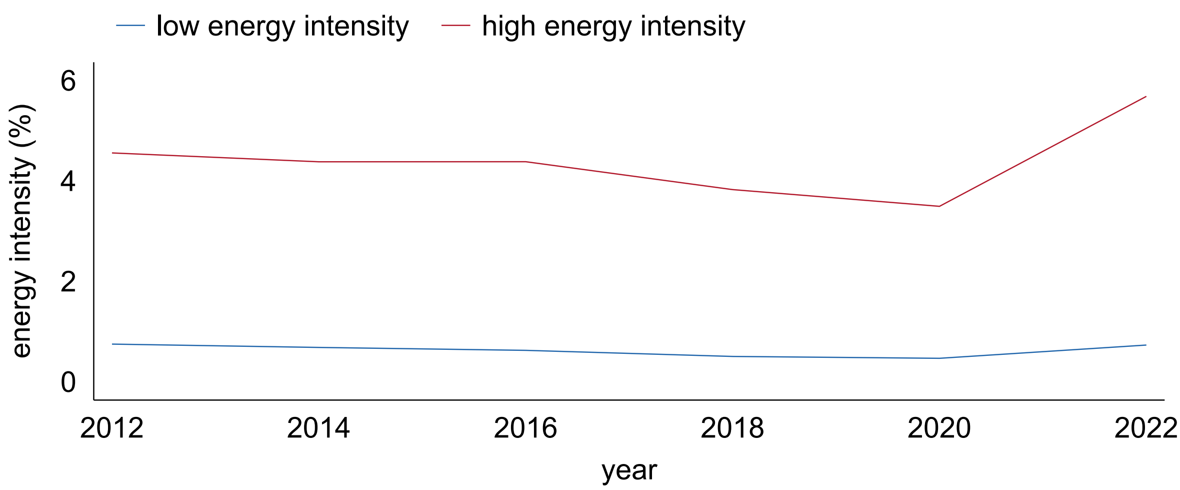


Figure 2: Dynamics of average energy intensity, low-energy-intensity vs high-energy-intensity firms.

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 the 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 6a and 6b of Figure 6 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 6c and 6d of Figure 6 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.[12] 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.

6 Effect of the Shock on Bank Lending

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

$$credit\_growth_{fbt} = \alpha + \sum_{\tau=T_1}^{T_2} \beta_\tau \left(1_{\bar{EI}_f=high} \times 1_{t=\tau}\right) + \delta_f + \delta_{sector(f)t} + \delta_{bt} + \varepsilon_{fbt} \tag{6.1}$$

$credit\_growth_{fbt}$ 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 $\times$ 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 $\times$ 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, as our data ends in 2023Q4, 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.

12. Average prices are higher than the aggregate price in Figure 1, suggesting that firms that consume a large amount of energy pay lower prices.

6.1 Negative Effect on Bank Credit Growth

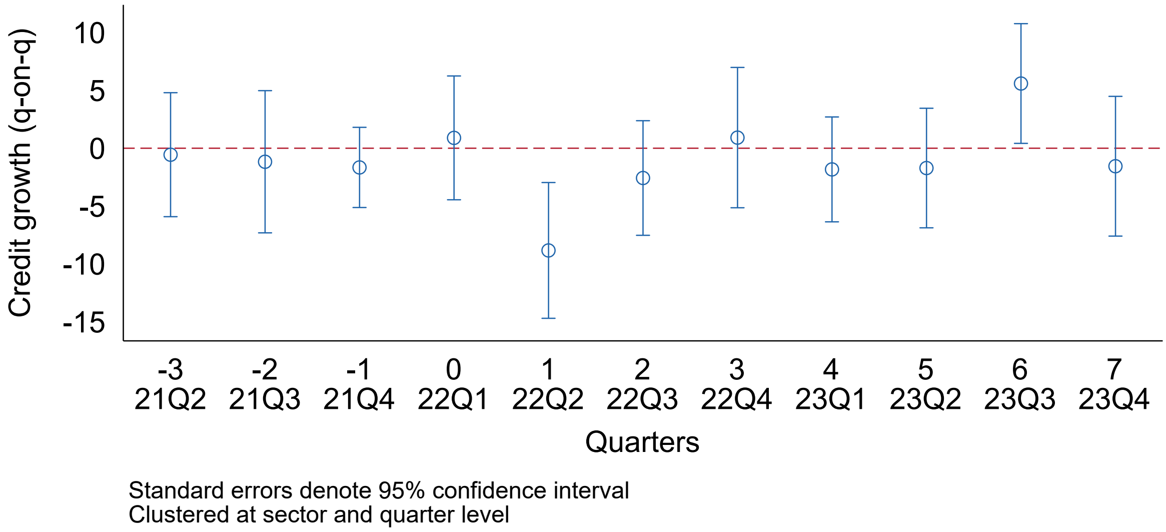
First, we show that, on average, high-energy-intensive firms' credit growth fell relative to that of low-energy-intensive firms after the invasion. This fall in credit growth is more pronounced for firms with higher energy intensity, supporting the hypothesis that energy intensity and not some other unobserved characteristic drives this result. The result is robust to different measures of energy intensity. We also demonstrate that measuring energy intensity at firm level, which allows us to account for industry-time fixed effects, is important.

Column 1 of Table 1 and Panel 3a of Figure 3 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 second quarter of 2022, 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 the second quarter of 2022, but the difference is not statistically significant. Because of this lack of persistence, we focus in our further results on the short-run effect on credit growth in the second quarter of 2022, the quarter immediately after the shock. Credit growth increases in the third quarter of 2023, a time when energy price uncertainty started to come down as it became clear that European gas stores were filled for the winter. In contrast to the decline in the second quarter of 2022, this increase is not robustly significant across specifications. Panel 3b shows that even within an industry, credit growth fell more for high-energy-intensity firms.

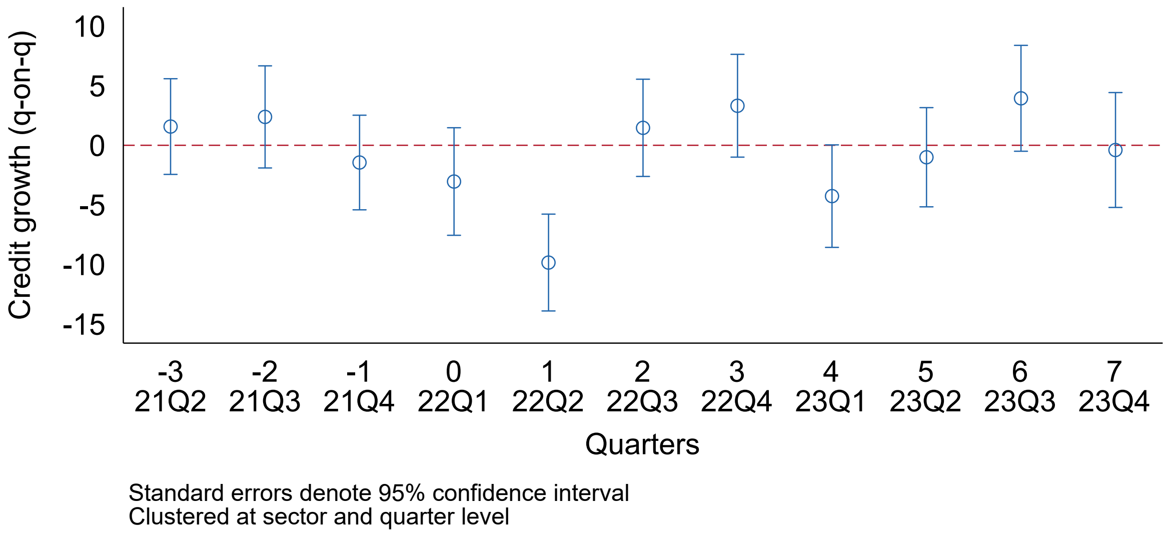
The economic magnitude of this effect is comparable to the responses of credit to other shocks. For example, Jiménez et al. (2014) report that banks increase lending to risky firms by 19 percent in response to a one percentage point decline in the monetary policy rate. Moreover, Amiti and Weinstein (2018) report that a negative credit supply shock associated with a bank failure leads to a decline in lending of that bank by 9 percent, while a positive credit supply shock associated with a capital injection leads to an increase in lending of that bank by 6.5 percent.

A back-of-the-envelope calculation can further help to put the macroeconomic importance of this shock into perspective: the average energy-intensive firm had outstanding loans of around 2.4 Mio. EUR prior to the shock. 8.75 percentage point higher bank credit growth corresponds to around 212.000 EUR more credit per firm, or, with 1045 energy-intensive firms, 221.2 Mio. EUR in the aggregate. Lending to the manufacturing sector increased by about 4 bn EUR over the period, such that aggregate credit would have increased by around 5.5 percent more, had high-energy-intensive firms borrowed as much as low-energy-intensive firms.

Columns 2 to 5 of Table 1 shows that controlling for bank × time, industry × time, and firm fixed effects is crucial to remove differences in trends across high- and low-energy-intensity firms. In particular, including only sector-time fixed effects flips the sign of the estimated coefficient, showing that energy-intensive firms tend to be in industries where all firms borrowed more in response to the energy price shock (Columns 3 and 5). Including only bank-time fixed effects also



(a) Across industry measure of energy intensity



(b) Within industry measure of energy intensity

Figure 3: Effects of the energy price shock on credit growth

Note: This figure reports the coefficients β_τ obtained by estimating equation 6.1. Period: 2019Q4-2023Q4. Source: Credit register of the Danish Central Bank, Statistics Denmark and own calculations.

Table 1: Baseline results

Note: This table shows results of estimating alternative versions of equation 6.1. It reports the β_{2022Q2} coefficients, with t-statistics in parentheses. The dependent variable is credit growth, as defined in equation 5.1. Column 1 is the baseline, with firm fixed effects, four-digit industry × time fixed effects and bank × time fixed effects. Column 2 removes firm fixed effects, Column 3 removes firm and bank × time fixed effects, Column 4 removes firm and industry × 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 × 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 × Time FE	Yes	Yes	Yes	No	No
Bank × 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

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

flips the sign of the coefficient, indicating that energy-intensive firms tend to borrow from the same banks (Columns 4 and 5), and that these banks extended more credit to all firms following the energy price shock. Moreover, including sector-time fixed effects substantially decreases the estimate compared to including only bank-time fixed effects (Columns 2 and 4).

These results show that accounting for granular bank-time and sector-time fixed effects is important to infer which channels are important for the propagation of the energy price shock. That we observe a decline in credit growth for exposed firms following the energy price shock suggests, drawing on the theoretical predictions in Section 3 that it is not the working capital channel, but rather one of the other four channels that drives the results.

6.2 Decomposition of Credit

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). Accordingly, the different theoretical channels discussed in Section 3 make different predictions about which credit instruments should be most affected by the energy price shock. We therefore decompose credit growth into the growth of its various components. We first break it down into different instrument types and then into new versus preexisting loans.

Suppose there are two instruments, so that total outstanding credit is the sum of outstanding credit of instruments 1 and 2, $C_{fbt} \equiv C^1_{fbt} + C^2_{fbt}$. Taking first differences and dividing by the average of outstanding total credit between $t-1$ and t, we obtain

$$credit\_growth_{fbt} = growth\_cont^1_{fbt} + growth\_cont^2_{fbt}, \tag{6.2}$$

where

$$growth\_cont^j_{fbt} \equiv 100 \times \frac{C^j_{fbt} - C^j_{fbt-1}}{0.5\left(C_{fbt} + C_{fbt-1}\right)}, \tag{6.3}$$

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 estimate the following variant of the regression model 6.1, substituting credit growth with the growth contribution terms:

$$growth\_cont^j_{fbt} = \alpha^j + \sum_{\tau=T_1}^{T_2} \beta^j_\tau \left(1_{\bar{EI}_f=high} \times 1_{t=\tau}\right) + \delta^j_f + \delta^j_{sector(f)t} + \delta^j_{bt} + \varepsilon^j_{fbt} \tag{6.4}$$

By construction, since these decomposed regressions contain the same regressors as the original regression, the coefficients β^j_τ from the decomposed regressions 6.4 will sum up to the coefficients β_τ in equation 6.1. 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.

The top panel of Table 2 shows 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.

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 2 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.

That the overall decline in credit growth is driven by preexisting credit lines and credit cards as opposed to C&I loans and mortgages suggest an important role for the precautionary savings channel or the credit risk channel, as opposed to the investment channel.

Table 2: Decomposition of credit growth

Note: This table shows results of estimating alternative versions of equation 6.1, replacing credit growth with its decomposition 6.3 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 $\times$ 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 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 $\times$ 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 $\times$ Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank $\times$ 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

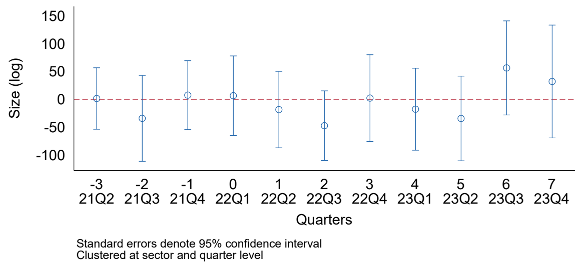
	(1) All Loans	(2) Trade Credit	(3) Mortgages	(4) Credit Lines	(5) Term Loans	(6) Leasing	(7) Credit Cards	(8) Other Loans
High EI $\times$ 22Q2	-0.468	-0.0145	0.206	-1.358*	0.333	0.678	-0.0430	-0.269
	(-0.58)	(.)	(0.87)	(-2.28)	(0.57)	(2.08)	(.)	(-1.74)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector $\times$ Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank $\times$ 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
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

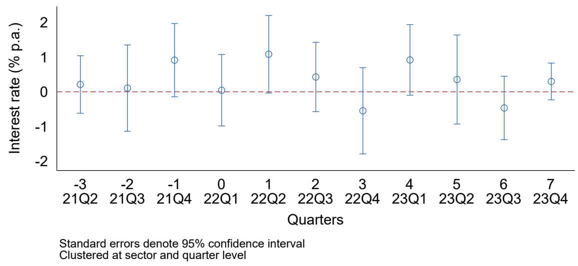
(c) Preexisting loans

	(1) All Loans	(2) Trade Credit	(3) Mortgages	(4) Credit Lines	(5) Term Loans	(6) Leasing	(7) Credit Cards	(8) Other Loans
High EI $\times$ 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 $\times$ Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank $\times$ 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

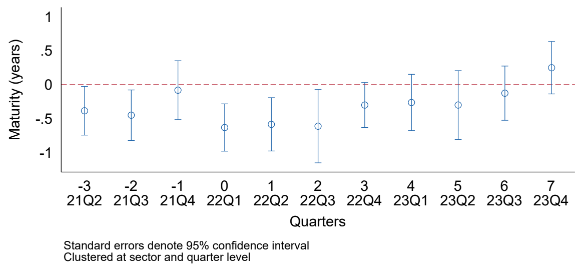
t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$



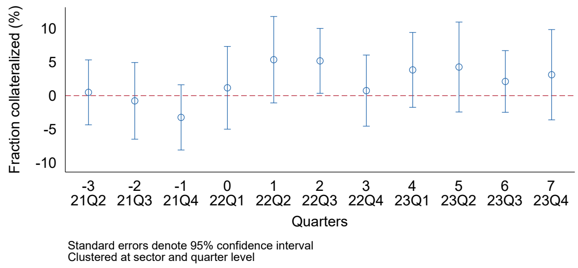
(a) Loan size



(b) Interest rate



(c) Maturity



(d) Share collateralized

Figure 4: Effects of the energy price shock on new loan terms

Note: This figure shows the results of estimating equation 6.1, replacing credit growth with loan terms on new loans. Period: 2019Q4-2023Q4. Source: Credit register of the Danish Central Bank, Statistics Denmark and own calculations.

6.3 Adverse Effect 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.

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 4 shows the results where we estimate variants of specification 6.1 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, 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.

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:

$$
\begin{aligned}
r^m_{lfbt} - r^m_t = \alpha + \sum_{\tau=T_1}^{T_2} \beta_\tau \left(1_{\bar{EI}(f)=high} \times 1_{t=\tau} \right) \\
+ \delta_{maturity(l)} + \delta_{instrument(l)} + \delta_{collateralized(l)} \\
+ \delta_f + \delta_{risk(f,t)} + \delta_{bt} + \varepsilon_{lfbt}.
\end{aligned} \tag{6.5}
$$

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 3 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.

7 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

Table 3: Loan-level credit spread regressions

Note: This table shows the results of estimating various variants of equation 6.5. 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

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

estimate the following regression:

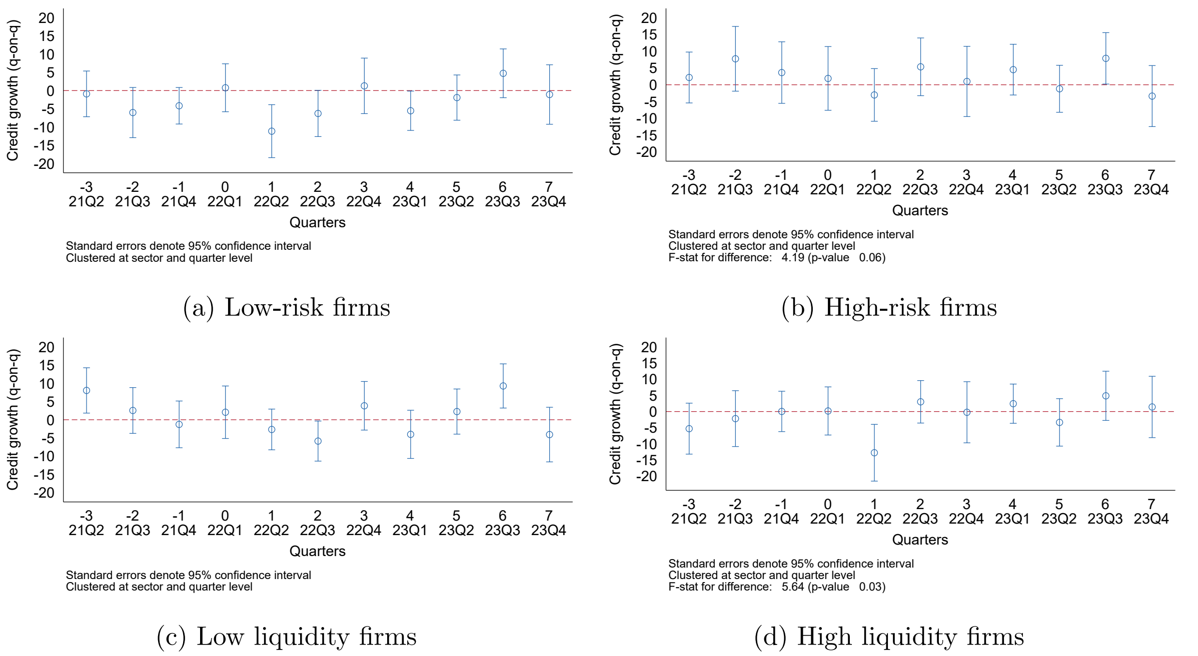
$$\begin{aligned} credit\_growth_{fbt} = \alpha &+ \sum_{\tau=T_1}^{T_2} \beta^1_\tau \left(1_{\bar{EI}_f=high} \times 1_{\text{Group 1},ft} \times 1_{t=\tau}\right) \\ &+ \sum_{\tau=T_1}^{T_2} \beta^2_\tau \left(1_{\bar{EI}_f=high} \times 1_{\text{Group 2},ft} \times 1_{t=\tau}\right) \\ &+ \sum_{\tau=T_1}^{T_2} \gamma_\tau \left(1_{\text{Group 2},ft} \times 1_{t=\tau}\right) + \delta_f + \delta_{industry(f)t} + \delta_{bt} + \varepsilon_{fbt} \end{aligned} \tag{7.1}$$

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.[13] For example, if we sort firms according to their 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.

13. 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 and group-specific medians are similar across groups.

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 two sources of heterogeneity: ex-ante riskiness and liquidity. In the appendix, we further discuss two other salient firm characteristics, namely size and age.



(a) Low-risk firms

(b) High-risk firms

(c) Low liquidity firms

(d) High liquidity firms

Figure 5: Effects of the energy price shock on the credit growth of different types of firms

Note: This figure shows the results of estimating equation 7.1. Period: 2019Q4-2023Q4. Source: Credit register of the Danish Central Bank, Statistics Denmark and own calculations.

Table 4: Heterogeneous effects on credit growth

Note: This table shows results of estimating alternative versions of equation 7.1. 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 5.1. All specifications include firm fixed effects, four-digit industry $\times$ time fixed effects and bank $\times$ time fixed effects. Column 1 splits firms according to their ex-ante bank-reported default probability at the 75th percentile. Column 2 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 3 splits firms according to age, with firms aged 20+ years classified as old. Column 4 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) Riskiness	(2) Size	(3) Age	(4) Liquidity
High EI $\times$ 22Q2 $\times$ low def. risk	-11.04**			

Continued on next page

	(2) Riskiness	(3) Size	(4) Age	(5) Liquidity
	(-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
Sector × Time FE	Yes	Yes	Yes	Yes
Bank × Time FE	Yes	Yes	Yes	Yes
R2	0.130	0.130	0.130	0.129
Obs.	43281	43281	43281	43184
F-test $\beta^1 = \beta^2$	4.143	14.94	0.410	5.745
p-value	0.0599	0.00153	0.531	0.0300

Continued on next page

	(2) Riskiness	(3) Size	(4) Age	(5) Liquidity
F-test $\beta^2 + \gamma = 0$	8.167	2.406	3.692	0.333
p-value	0.0120	0.142	0.0739	0.572

t statistics in parentheses

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

7.1 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 4 and Panels 5a and 5b of Figure 5 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.

7.2 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 (Almeida, Campello, and Weisbach 2004; Almeida, Campello, Laranjeira, and Weisbrenner 2012; Bolton et al. 2011; Eisfeldt and Muir 2016). Moreover, firms with higher exposure to aggregate risk tend to rely more on cash than on credit lines (Sufi 2009; V. V. Acharya, Davydenko, and Strebulaev 2012; V. V. Acharya et al. 2013; V. Acharya et al. 2014). We expect that low-liquidity firms rely less on cash and more on credit lines for liquidity management, and therefore to reduce credit less in response to a positive energy cost shock. We expect that unconstrained firms at risk of becoming liquidity-constrained have a more elastic credit demand to the shock, and to reduce credit more .

Column 5 of Table 4 and Panels 5c and 5d of Figure 5 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.

Table 6: Heterogeneous effects on loan spreads

Note: This table shows the results of estimating various variants of equation 6.5. 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 according to their ex-ante bank-reported default probability at the 75th percentile. Column 2 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 3 splits firms according to age, with firms aged 20+ years classified as old. Column 4 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.

	(2) Riskiness	(3) Size	(4) Age	(5) Liquidity
22Q2 × high def. risk	0.321			
	(0.39)			

Continued on next page

	(2) Riskiness	(3) Size	(4) Age	(5) Liquidity
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
Sector × Time FE	Yes	Yes	Yes	Yes
Bank × Time FE	Yes	Yes	Yes	Yes
R2	0.700	0.699	0.699	0.698
Obs.	23083	23083	23083	23075
F-test $\beta^1 = \beta^2$	1.827	3.582	5.894	0.181
p-value	0.194	0.0755	0.0266	0.676
F-test $\beta^2 + \gamma = 0$	7.434	0.334	6.136	3.957

Continued on next page

	(2) Riskiness	(3) Size	(4) Age	(5) Liquidity
p-value	0.0144	0.571	0.0241	0.0630

t statistics in parentheses

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

Table 6 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 conditions.

8 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, implying that our baseline definition of energy intensity is not necessary to obtain the results. Third, in horse race regressions with other salient firm characteristics that proxy exposure to confounding shocks, the difference in energy intensity remains the main driver in the observed credit growth.

8.1 Finer Quantiles

Column 7 of Table 8 shows 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 6.1 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.

Table 8: Alternative measures of energy intensity

Note: This table shows variants of equation 6.1, 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 5.1. 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
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

8.2 Alternative Definitions of Energy Intensity

Table 8 shows 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 8.

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 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. This robustness check sharpens identification, as it adds the timing of the price reset of firms' energy supply contract as a predetermined and likely exogenous source of variation: firms whose energy contract expires early in 2022 will face a larger increase in energy costs compared to firms whose contract expires late in 2022. The change in the energy price is therefore a good proxy for the timing of the energy contract. We split firms at the 75th percentile of the change in energy intensity. The results are reported in Column 2 of Table 8.

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 f as

$$EI_{ft}^{tech} = \frac{energy\_gj_{ft}}{employment_{ft}}. \tag{8.1}$$

$energy\_gj_{ft}$ 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 8.

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 8.

Continuous 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 the distribution of energy intensity, similar to that firm size, has a long right tail. The results are reported in Column 8 of Table 8.

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.

8.3 Horse Race Regressions with Other Firm Characteristics

Table 12 in Appendix B shows that the effect is due to differences in treatment and control firms' energy intensity, not size, age, or leverage. These other firm characteristics proxy other channels through which firms might be differently exposed to the economic disruption following the Russian invasion of Ukraine. For example, larger firms are typically more likely to export and at the same time rely more on international supply chains (Melitz (2003) and Ersahin, Giannetti, and Huang (2024)). Younger firms are more sensitive to changes in macroeconomic uncertainty, as they rely more on growth options (Bloom (2009) and Clymo and Rozsypal (2022)). More leveraged firms are riskier, and therefore more exposed to changes in financial conditions (Palazzo and Yamarthy (2022)).

We estimate variants of equation 6.1 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 12) remains stable across these different specifications.

In light of the reduction in average credit growth following the energy price shock, 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.

9 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. The shock caused a sharp decline in credit growth in the quarter following the invasion, resulting mainly from low-risk firms reducing their credit demand 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, highlighting the importance of understanding financial frictions on both the credit demand and supply sides in order to assess the impact of such fluctuations.

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.

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Internet Appendix

A Descriptive Statistics

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

A.1 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 5.2. The accounting data are annual for 2012-2022; the energy use data is bi-annual for 2012-2022. Source: Statistics Denmark 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.2 Firm-Bank Level Summary Statistics

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 $\times$ firm $\times$ 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 5.2. Source: Credit register of the Danish Central Bank, 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				

Continued on next page

	Full dataset mean/sd	Matched dataset mean/sd	Low EI mean/sd	High EI mean/sd
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

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.

A.3 Decomposing the increase in energy intensity

Figure 6 displays a decomposition of the of the energy intensity time series from Figure 2. It shows that the numerator of energy intensity, energy consumption, and its denominator, revenue, increased. The increase in revenue was however not as large as the increase in the numerator, such that energy intensity increased overall. The bottom panels decompose the value of energy consumption in the price of energy and the quantity of energy consumed, showing that the increase in energy intensity comes from an increase in energy prices, with little to no substitution away from energy.

B Horse Race Regressions

Table 12 extends the baseline specification to include interactions between time and other firm characteristics. We split firms into two groups, Group 1 and Group 2, according to some firm characteristic in the year prior to the energy price shock, for example size or age. The regression specification is

$$\begin{aligned} credit\_growth_{fbt} = \alpha &+ \sum_{\tau=T_1}^{T_2} \beta_\tau \left(1_{\bar{EI}_f=high} \times 1_{t=\tau}\right) \\ &+ \sum_{\tau=T_1}^{T_2} \gamma_\tau \left(1_{\text{Group}_{f,2021}=2} \times 1_{t=\tau}\right) \\ &+ \delta_f + \delta_{sector(f)t} + \delta_{bt} + \varepsilon_{fbt} \end{aligned} \tag{B.1}$$

The coefficients γ_τ measure differences between Group 1 firms and Group 2 firms over time. We find that including these differences does not change the effect of the baseline coefficients, suggesting that it is differences in energy intensity and not some other firm characteristics that drive the main result. This supports the interpretation of the effect as a causal effect of the energy price shock.

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

(c) Energy price (DKK/GJ) (d) Energy cons. quantity (1000s of GJ)

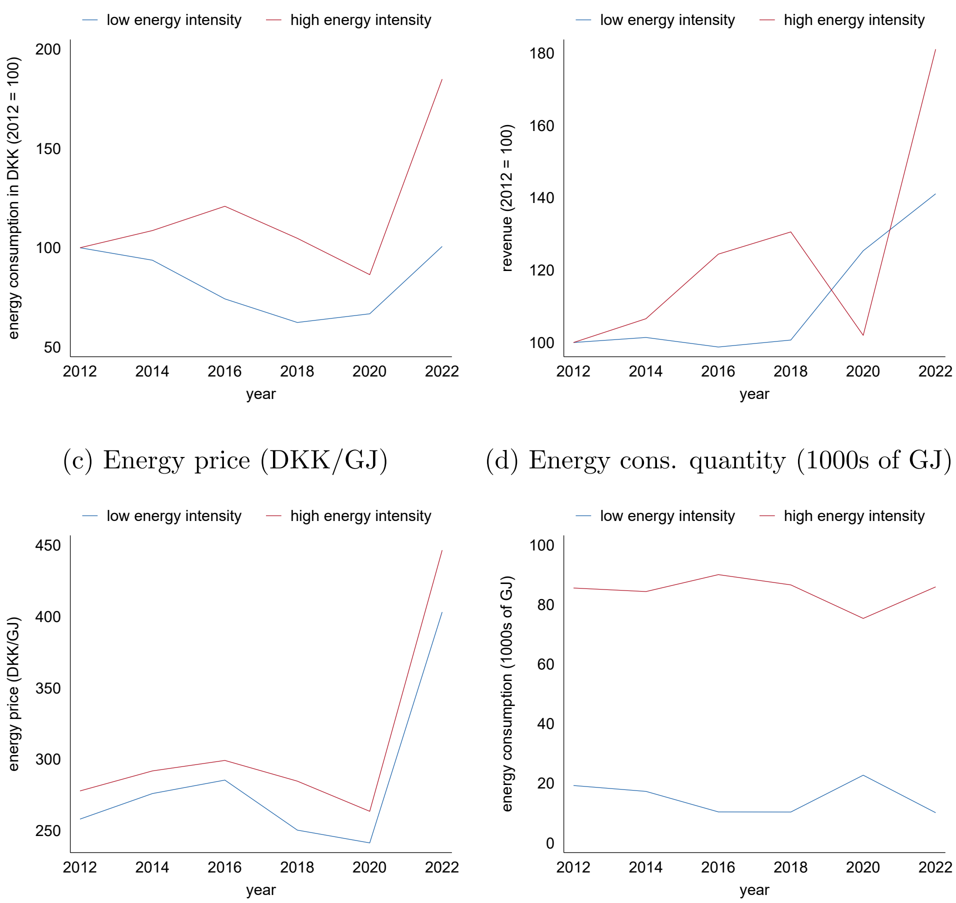

Figure 6: Dynamics of average energy intensity, prices and consumption, low-energy-intensity vs high-energy-intensity firms.

Note: Panel 6a shows the numerator of the energy intensity time series displayed in Figure 2, energy consumption, Panel 6b their denominator, revenue. Panels 6c and 6d further decompose the numerator into the average energy price and the average energy quantity.

Table 12: Controlling for other firm characteristics

Note: This table shows results of estimating alternative versions of equation B.1. It reports the β_{2022Q2} and γ_{2022Q2} coefficients, with t-statistics in parentheses. The dependent variable is credit growth, as defined in equation 5.1. 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 Empirical Results

This section shows that smaller and younger firms see a larger decline in energy intensity.

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, Darmouni, Luck, and Plosser 2022). Therefore, we expect small firms to have a larger decline in credit growth than large firms.

Column 3 of Table 4 shows this to be the case. 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 4 shows 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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Niels Framroze Møller
Danmarks Nationalbank, Copenhagen, Denmark; email: nfm@nationalbanken.dk

Johannes Poeschl (corresponding author)
European Central Bank, Frankfurt am Main, Germany; email: johannes.poschl@ecb.europa.eu

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

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