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Nobody's gonna slow me down? The effects of a transportation cost shock on firm performance and behavior☆

Catarina Branco[a], Dirk C. Dohse[b], João Pereira dos Santos[c,1,*], José Tavares[d]

[a] Nova School of Business and Economics, Universidade Nova de Lisboa, Campus de Carcavelos, Rua da Holanda 1, Carcavelos 2775-405, Portugal
[b] Kiel Institute for the World Economy, Kiellinie 66, Kiel 24105, Germany
[c] ISEG – University of Lisbon, RWI – Leibniz Institute for Economic Research, IZA – Institute for Labor Economics, REM/UECE
[d] Nova School of Business and Economics and Centre for Economic Policy Research (CEPR), London, UK

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ABSTRACT

We study the firm-level responses to a substantial increase in transportation costs in the wake of a quasi-experiment that introduced tolls in a subset of Portuguese highways. Exploiting a unique dataset encompassing the universe of Portuguese private firms, we find that the introduction of tolls caused a substantial decrease in turnover (−10.2%) and productivity (−4.3%) in treated firms *vis-à-vis* firms in the comparison group. In response to the tolls, firms substantially cut employment-related expenses and purchases of other inputs. Labor costs were reduced by both employment cuts and a decrease in average wages. While firms did not increase inventory, there is some evidence for increased firm exit, in particular by firms in tradables sectors.

1. Introduction

Transport infrastructure is key to economic development. Not only does it allow for the circulation of people, it is also fundamental to the physical exchange of goods. At the same time, transport infrastructure is rather expensive. Thus, it is essential to understand the relationship between transport infrastructure and economic outcomes in order to adequately design transport policy. While studies on the effect of transport infrastructure on aggregate economic outcomes are abundant (Redding and Turner, 2015), micro level studies on the effect of transport infrastructure on firm performance are rather limited (Holl, 2016).[2] This paper contributes to the literature by taking a deep and comprehensive look into the firm-level behavioral responses to a massive transportation cost shock. Making use of a unique micro-level data set encompassing the whole universe of Portuguese private firms with precise geo-location for more than 120 thousand postal code

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* Corresponding author.
E-mail addresses: dirk.dohse@ifw-kiel.de (D.C. Dohse), joao.santos@iseg.ulisboa.pt (J. Pereira dos Santos), jtavares@novasbe.pt (J. Tavares).

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[2] There are some notable exceptions, which include the effect of transport infrastructure on firms' exports (Martincus et al., 2012; Martincus and Blyde, 2013; Martincus et al., 2014; 2017), inventories (Datta, 2012; Li and Li, 2013; Shirley and Winston, 2004), and productivity (Lall et al., 2004; Gibbons et al., 2019; Holl, 2012; 2016; Martin-Barroso et al., 2015; Graham, 2007b; 2007a; Fiorini et al., 2021).

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levels, we rigorously analyze how introducing tolls on previously toll-free highways affects various dimensions of firm performance. Importantly, we also examine how firms react to mitigate the adverse effects of the transportation cost shock.

Estimating the causal effect of transport infrastructure on economic outcomes is not straightforward, as this kind of infrastructure is usually not randomly assigned. Therefore, it is hard to pinpoint if firm-level outcomes vary due to the change in transportation costs or due to other, unobserved, characteristics. A common solution in the literature for this endogeneity problem is to use an Instrumental Variable (IV) or the inconsequential places approach (Redding and Turner, 2015). Although less common, some papers alternatively rely on a natural experiment.[3] The latter is exactly what we do in this paper.

The SCUT highway system started being built in 1990 and came into completion in 2008 in Portugal. Portuguese authorities made this network toll free for its users, hence the name SCUT ("**S**em **C**usto para o **Ut**ilizador" or "Without Cost for the User"). One of the main motivations behind its conception was to create an alternative network to the old and deteriorated (municipal) roads. This new and more modern system sought to make travelling safer and a lot faster. By the end of 2008, SCUTs accounted for almost 1000 km, nearly a third of the Portuguese highway grid at that time (Statistics Portugal, INE, 2008).

All of this changed in 2010. At the onset of the European sovereign debt crisis, the Portuguese government was forced to consolidate its financial position, cutting spending and increasing revenues (Financial Times, Wise, 2013). Thus, the national budget could no longer sustain the provision of a toll-free network. Tolls were then introduced in two waves, first by the end of 2010 and, then, by the end of 2011.

This event provides us with a unique natural experiment, which allows one to study the impact of an exogenous variation of transportation costs on firm related outcomes.[4] Tolls were introduced purely out of the need to balance the government budget. In other words, this decision was made without special consideration of the firms (or municipalities) affected by the decision. Two earlier studies used the same natural experiment to assess the impact of an unexpected introduction of road tolls on road safety and regional economic performance. Pereira et al. (2021) show that the introduction of tolls led to an increase of the number of (light) accidents and road injuries, whereas Audretsch et al. (2020) find that it negatively impacted macroeconomic outcomes (numbers of firms and employment) in the affected municipalities. The current paper goes well beyond previous research, making use of a novel firm-level micro dataset, encompassing more than 300,000 firms, merged with precise geo-location such that we are able to compute the distance to the nearest SCUT highway entry point. We investigate the medium-run impact of tolls on different firm-level performance indicators (including turnover, profits, and labor productivity), and we analyze a wide array of firms' adaptation strategies.

Our findings provide important insights into the various firm-level effects and behavioral responses to a massive transportation cost shock that are new to the literature. In our baseline model, we define treated firms as those that are closer (i.e., those in the first quintile of distance) to a SCUT highway and find that the introduction of tolls caused a 10.2% decrease in turnover and a 4.3% decrease in labor productivity in these firms *vis-à-vis* firms in the remaining, more distant, areas. Profits were not affected, suggesting that the firms were able to pass through the burden of tolls (at least partly) to other economic agents.

An innovative feature of our paper is how it carefully analyzes several measures by which the firms could adapt to the transportation cost shock. An obvious reaction is cost cutting. We find that treated firms significantly reduced their total expenses by 8%, on average. The shock led to a cut of similar magnitudes in the purchase of goods and services as well as in employment related expenses. Employment cost cutting was reached by a combination of reduced full-time employment and lower average wages.

Firms could also adapt by changing their sales strategy, focusing on sales markets in which the transport cost increase on domestic (SCUT-) highways plays a lesser role. Here we find that domestic turnover and exports to the EU were reduced in a similar order of magnitude. By contrast, exports to markets outside the EU (the "rest of the world") were not significantly reduced, which may be due to the fact that only a smaller share of the total transportation costs of overseas goods is affected by tolls on domestic highways. We find no evidence for an increase in inventory, but we observe a very small increase in firm exit, namely by firms which depend strongly on transportation (tradables sectors) and by low productivity firms.

The majority of the effects for all these outcomes are felt in the long-term, i.e., they are still persistent nine years after the introduction of tolls. Moreover, the results are robust to a wide variety of checks, including slightly modified definitions of treatment, tests for spillover effects, the insertion of several vectors of fixed effects, the presence of alternative highways, and they hold in particular subsamples and using different empirical specifications.

The paper is structured as follows. Section 2 briefly surveys the related literature and details the institutional background, while Section 3 discusses the conceptual framework. Section 4 presents the data and discusses the methodology and possible identification threats. Section 5 shows how the tolls affected key measures of firm performance whereas Section 6 presents and discusses firm-level responses to the transportation cost shock. Section 7 presents a plethora of robustness checks. Section 8 concludes.

2. Literature review and institutional background

2.1. Related literature

The majority of research on the economic impact of infrastructure provision and pricing focuses on the macro (country or region) level and looks at macroeconomic variables. Some of the most prominent papers study the impact of transport infrastructure on population growth (Baum-Snow, 2007; Michaels et al., 2012; Garcia-López et al., 2015; Baum-Snow et al., 2017; 2020; Jedwab and Storeygard, 2022), aggregate trade (Duranton et al., 2014; Storeygard, 2016; Donaldson, 2018; Coşar et al., 2022), and GDP/ aggregate income (Banerjee et al., 2012; Faber, 2014; Jaworski and Kitchens, 2019; He et al., 2020).[5] However, studies carried out at aggregate levels of analysis provide little insights into the actual mechanisms by which improvements or deterioration of infrastructure affect firm performance (Haughwout, 2002). Moreover, these studies ignore mobility of firms and responses to local price changes caused by modifications in infrastructure provision and pricing (Holl, 2006).

Against this background, researchers have begun to analyze the effects of transportation infrastructure on firm-level indicators. Transportation infrastructure can affect firm performance through several channels which is reflected in a variety of empirical approaches. Moreover, the country context remains important, and the effects found in a developing country context are often larger than those found in a developed country context.

[3] For some examples of papers which also use a natural experiment as source of exogenous variation in infrastructure see Martincus et al. (2014); Martincus and Blyde (2013), and Brooks and Donovan (2020).

[4] In Portugal, the transportation of goods is mainly done through road transports. According to Statistics Portugal (2015), in 2010, 76% of goods were delivered via road transportation. Moreover, there were no changes in the provision or in the capacity of railroads in this period. Municipal roads were also constant in our sample period.

[5] A related line of research deals with the impact of transport infrastructure and transportation costs on spatial structure (Baum-Snow, 2020; Behrens et al., 2018).

Many of the earlier studies focused on developed countries. Holl (2012) examines the influence of the Spanish transportation infrastructure on firm-level productivity through its effects on market potential, finding that growth of market access has a positive impact on firm-level output growth. In follow-up research, Holl (2006) uses a geo-coded micro-level panel dataset for Spanish manufacturing firms and finds an elasticity of productivity with respect to access to highways in the range of 1.3-1.7%.[6] Using firm-level panel data for Britain, Gibbons et al. (2019) estimate the impact of new road infrastructure on employment and labor productivity. They measure exposure to transport improvements through changes in accessibility through journey times and find that improving accessibility by 1% leads to a 0.3-0.4% increase in overall employment and 0.2% increase in output per worker. While we are not aware of firm-level studies for the US, recent work by Herzog (2021) on the effects of the US Interstate Highway System on local economic activity finds that improved market access had large effects on employment and modest effects on wages in the long-run.[7]

Several studies suggest that the effects of infrastructure provision on firm performance are particularly strong in a developing country context. Chauvet and Ferry, 2021 investigate the relationship between taxation and firm performance in developing countries, finding that taxation benefits firm growth in developing countries, especially in lower-income countries, through the financing of public infrastructure. Barzin et al. (2018) estimate the effect of roads on firms' output growth in Colombia, finding elasticities of output with respect to road infrastructure ranging from 0.13% to 0.15%, which is larger than what is found in comparable work for developed countries.

There is a body of research that investigates the effects of the Golden Quadrilateral, a large infrastructure project in India with highways established from 2001 onwards. Asturias et al. (2019) estimate that this infrastructure led to real income gains in the manufacturing sector of 2.7%, about 7% of which was caused by gains in allocative efficiency. Ghani et al. (2016) find that manufacturing output, numbers of plants, and productivity soared by around 25–45% over 10 years, in areas within 10 km of the new highways. The effects on firm productivity increases are confirmed by Abeberese and Chen (2022). Lastly, Datta (2012) finds that firms in cities affected by the project were able to reduce their average stock of input inventories by 6–12 days' worth of production.

Transportation infrastructure also impacts trade. Fan et al. (2019) examine the effects of new highways in China between 1999 and 2010 and find that these constructions increased aggregate exports by 10% and domestic trade by 14%. Duranton (2015) estimates the trade effects of major roads in Colombia, showing that road distance between cities is a major impediment to trade with an elasticity of trade with respect to distance of around -0.6. Martincus et al. (2017) use the Inca road network to evaluate changes in road infrastructure in Peru and estimate that about one fourth of growth in firm exports between 2003 and 2010 can be attributed to upgrades of domestic transport infrastructure.

While these papers focus on infrastructure provision or quality improvements of existing infrastructure, relatively little is known about the long-term firm-level effects of infrastructure deterioration or permanent increases in the price of important transport infrastructure. Martincus and Blyde (2013) make use of the 2010 earthquake in Chile that made several roads impassable as an exogenous source of variation in available infrastructure and thereby in transport costs. They find that diminished transportation infrastructure had a significant negative impact on firms' exports. In addition, Martincus et al. (2014) exploit exogenous variation in transportation costs resulting from the temporary closure of the main bridge connecting Uruguay and Argentina, concluding that a 1% increase in transport costs results in a 6.5% reduction in firms' export values.

The effects of natural disasters or vanishing bridges are, however, not directly comparable to the introduction of road tolls, as they led to a complete closure of the affected roads and are temporary in nature, whereas road tolls – such as the tolls on SCUT highways in Portugal – often have a long-run duration which makes it more likely that they have long-term effects as well. Research on the firm-level effects of road tolls is very scarce. Although there exist some papers headlining that road tolls can have effects on travel decisions and traffic levels (Meland et al., 2010; Díez-Gutiérrez et al., 2019), these papers do not investigate the economic consequences of the tolls. The few papers that study economic effects of road tolls focus on regional-level effects rather than firm-level effects. Recent examples include Chen and He (2015) studying the effect of road tolls on provincial GDP growth and inter-regional trade in China, and Audretsch et al. (2020) studying the effect of road tolls on the number of firms and regional employment in Portugal.

2.2. Institutional background

Since joining the EU in 1986, Portugal invested substantial resources to close the gap with the core of Europe in terms of road infrastructure (Fernandes and Viegas, 1999; Melo et al., 2022).[8] The large scale of public funding allocated to transportation infrastructure and the rapid development of the Portuguese highway system makes Portugal an ideal case study to examine the economic effects of transportation infrastructure and has triggered a lot of important and insightful research (see, for instance Audretsch et al., 2020; Holl, 2004; Melo et al., 2022; Pereira and Andraz, 2005; Rocha, Melo, Afonso, de Abreu e Silva. During the 1990s, however, these investments became a heavy financial burden. The need to guarantee the necessary funds without breaching the EU rules on member state budget deficits spurred the cooperation with private enterprises through public private partnerships (PPPs) to expand and operate road infrastructures (Fernandes et al., 2005). In 1997, a new kind of PPP scheme was introduced: a system of modern, toll-free highways, the so-called SCUTs (acronym for "Sem Custos para o Utilizador"/without costs for the users).[9] Private investors were ensured a long-term rent paid by the central government budget based on the traffic volume and operation standards (Sarmento, 2010).[10]

This new PPP scheme allowed for a swift expansion of the highway system in Portugal at low initial costs for the public sector, and helped cut average travel time between Lisbon and the Spanish border (as well as between the capital and some areas) by more than 40%. However, these large investments also generated a severe pressure for the country's budget over the next 25–30 years (Sarmento, 2010; Santos and Santos, 2012). The SCUT highways were constructed between 1990 and 2008 (and mostly in the 1990s) at a cost of about 3 billion euros, and cover nearly 1000 km, i.e., about one-third of the total Portuguese highway system. The geographical distribution of the SCUT and non-SUCT highways can be seen in Fig. A.1 in the Appendix.

[6] In related work, Holl and Mariotti (2018) use detailed geo-referenced data to study the effects of highway development on firm-level performance in the Spanish logistics sector and show that highways have significant effects on firm performance, although with important spatial heterogeneity.

[7] From 1953 to 2010, a standard deviation rise in an average county's market access growth increased their employment growth by a quarter of a standard deviation and increased their wage growth by one seventh of a standard deviation.

[8] By 2017, Portugal had the fifth highest motorway density relative to population in the EU (Rocha et al., 2021).

[9] According to the Court of Accounts, these projects were financed essentially through loans from commercial banks (45%), the European Investment Bank (40%), and equity (12%). Fernandes et al. (2016) compute that the financing costs of SCUT highways are, on average, 370 basis points above the cost of raising public debt. Moreover, they argue that the transaction costs (which include banking fees and diligence costs and the impact of all cash distribution traps, such as reserve accounts or minimum-level of debt ratios) account for around 40% of that financial premium.

[10] The same rationale can be found, for example, in the UK, Spain, and Australia.

In the course of the European sovereign debt crisis, the financial strain on the central budget became so tough that the Portuguese authorities had no choice but to enforce sizeable tolls on the formerly toll-free SCUT highways. As the Financial Times wrote, “To help keep Portugal’s 78bn bailout on track, the government has been forced to introduce charges on more than 900 km of roads where there was previously none” (Financial Times of 25 August 2013). When the tolls were established in 2011, the price was 9 cents/km for cars, which was slightly higher than for the other highways (Audretsch et al., 2020) – and the cost increase for larger vehicles was even more substantial. In 2010, the President of the National Association of Public Road Transporters of Goods (ANTRAM) stated that the owner of a truck that circulated daily in the areas of the newly-tolled SCUT highways could face a monthly cost increase in the order of 2500 euros.[11] This massive cost increase had a substantial adverse impact on traffic and implied that many commercial users shunned the SCUT highways and increasingly used slower alternative options such as municipal roads. According to a study by the Institute for Road Infrastructures, traffic along the SCUT highways decreased substantially between the first quarter of 2011 and the first quarter of 2012. There were no noteworthy congestion cases on the SCUTs highways when tolls were introduced (INIR, 2011). This shock was purely driven by financial reasons and did not consider local conditions. The mayors of the SCUTs regions were against the introduction of tolls (even those who belonged to the same party as the national government), and there were massive protests from the local populations.[12]

With the improvement of the financial conditions, and in reaction to the decrease in traffic and the widespread criticism in the public, the new Portuguese socialist government decided to cut back the tolls on SCUT highways by 15% from 1 August 2016 onwards. This decision was supported by a report from the public entity responsible for managing the road infrastructure that estimated that decreasing the tolls by 15% would increase public revenues.[13]

3. Conceptual framework

This paper contributes to the literature on firm-level effects of transport infrastructure in several ways. Whereas the majority of research investigates the effects of infrastructure provision, the focus of this paper is on a price shock, i.e. a strong increase in the price of an already existing road infrastructure. Moreover, most of the above-mentioned papers on firm-level effects of transport infrastructure just look at single indicators of firm performance. A fact that is often overlooked is that firms can adapt to changes in the availability, price, and quality of infrastructure. Through adaptation measures, firms can influence to what degree they will be affected by disruptions. Adaptation measures can enhance their resilience and decrease the negative impact of the loss of infrastructure services (Kajitani and Tatano, 2014). Hence, to develop a better and more complete understanding of the complex firm-level effects of an infrastructure shock, it is not enough to look at the changes of single indicators of firm performance, but it is necessary to investigate the behavioral responses (adaptation measures) that firms have at their disposal as well.

To fill that gap we proceed in the following way: we begin with an assessment of firm-level performance measures that serve as a benchmark to help us compare our findings with the existing literature. In a second step, we expand the scope of the analysis to include firm-level adaptation, which is clearly an underexplored topic. This second step is not only important to draw a more complete picture of firm-level effects, but also to better understand whether firms are able to pass through the burden of the tolls – at least partially – to others, e.g., their employees or suppliers.

We analyze three related measures of firm performance in Section 5: Turnover (output), firm profits, and productivity. Turnover and profits appear as natural measures in this context because highway tolls are likely to affect both of them directly. Assume that each firm pursues a number of projects ordered by decreasing expected profitability. All projects that yield a profitability larger than or equal to zero will be pursued, whereas projects with (expected) negative profitability are cancelled. All else equal, the increase in transportation costs renders non-profitable some of the projects that were profitable before the introduction of tolls. As a consequence, a reduced number of projects is pursued and turnover is expected to decrease. Without any further adaptation measures, firm profits are expected to decrease as well as the number of profitable projects goes down and the profit margin of the remaining projects is lowered by the tolls. The potential effects of highway tolls on firm-level productivity are complex and the net-effect is difficult to predict. Transport cost changes can affect market size as well as the intensity of competition on goods markets (Holl, 2016). A transport cost shock can reduce market size, disturb the efficiency of cooperation with distant value chain partners, and reduce the intensity of competition, all of which tend to lower productivity. On the other hand, tolls might trigger a re-organization of production and induce other firm-level adaptation measures (discussed below) that might boost productivity.

Potential firm-level adaptation measures are manifold, and it is impossible to capture them completely.[14] Nevertheless, our unique firm-level dataset allows us to study several key measures in Section 6, including input cost cutting to suppliers and workers, changes of trade destinations, changes in inventory, and decisions to exit the market.

The most obvious reaction to an infrastructure price shock is cost cutting. Firms could try to shift the burden of the highway tolls – at least partly – to their suppliers or employees. We thus study the development of firm expenses after the shock, giving particular attention to the purchase of goods and services input and to the evolution of labor costs in terms of employment numbers and wages.

Firms can also adapt through changes in their sales strategy, by focusing on sales markets for which the transport cost increase on domestic (SCUT-) highways plays a lesser role. Therefore, we separately analyze how the tolls have affected firms’ domestic sales, their propensity to export, as well as their level of exports to the EU and to the rest of the world.

Changing inventory is another possible adaptation measure. In the empirical literature there is evidence for a decrease in inventory following the provision of rail or road infrastructure (Shirley and Winston, 2004; Datta, 2012; Li and Li, 2013). One might argue that a road price shock works in the opposite direction and could thus lead to an increase in inventory. However, things are complicated by the fact that reducing inventory is relatively easy, whereas building up new inventory often requires investment which might be prohibitively expensive.

Finally, the strongest firm-level reaction to a road price shock could be leaving the market (exit) or re-location.[15] Such a strong reaction is unlikely to happen for the majority of firms, but it could make sense for firms that are particularly dependent on road infrastructure or that had underperformed before the treatment set in (e.g., low productivity firms). We thus study market exit, distinguishing between firms in the

[11] Source: https://cnnportugal.iol.pt/economia/camioes/scut-portagens-custam-2-500-euros-por-mes-a-cada-camiao.

[12] See, for instance, https://www.jornaldenegocios.pt/empresas/transportes/detalhe/parlamento-rejeita-fim-das-portagens-na-via-do-infante.

[13] See, for instance, https://www.tsf.pt/economia/descer-portagens-nas-antigas-scut-e-bom-negocio.html.

[14] We are unable to analyze whether firms could pass through the burden of the tolls by increasing consumer prices. However, given that the large majority of firms in Portugal are small (Cabral, 2007), it is rather unlikely that they dispose of enough market power to set prices on consumer markets.

[15] One limitation is that we are not able to observe if an entrepreneur decides to close a firm in a given municipality and open a *different* firm in another area. Figueiredo et al. (2002) show that Portuguese entrepreneurs tend to have a strong home-bias in deciding where to locate their firms.

Table 1
Descriptive statistics for treatment and comparison groups in the baseline model (2006–2019).

	Comparison			Treated		
Key variables	Mean	Std. Dev.	N x T	Mean	Std. Dev.	N x T
Firm Performance						
Turnover	1,077,169	25,876,691	3,003,375	901,906	16,562,361	752,058
Profits (EBT)	49,348	4,826,669	3,003,375	44,309	2,184,065	752,058
Labor productivity	97,212	1,534,499	2,254,415	93,095	1,511,116	567,987
Firm Behavior						
Total expenses	1,131,480	27,122,302	3,003,375	943,963	17,734,916	752,058
Full-time paid employment	8.7	85.3	2,673,493	8.1	74.4	670,177
Average Wage	10,482	9232	2,254,415	10,265	8299	567,987
Domestic turnover	870,171	20,398,018	3,003,375	714,718	15,483,267	752,058
Exports	206,998	9,502,263	3,003,375	187,188	4,431,693	752,058
Inventory	221,386	2,609,658	3,003,375	211,276	1,882,638	752,058
Prob of exit	0.037	0.190	3,952,315	0.039	0.194	993,879

Notes: Profits are proxied using earnings before taxes. All indicators, with the exception of Probability of exit, are measured for the firms that existed in 2010. Descriptive statistics for the secondary variables studied in this paper are shown in Table A.2 in the Appendix.

tradable and non-tradable sectors on the one hand and between (pre-treatment) high- and low-productivity firms on the other hand.

4. Data and empirical approach

4.1. Data and variables

For the purpose of this study, we combine several datasets. The firm-level information comes from the *Central Balance Sheet*, and is harmonized and made available to researchers by *BPLim – Banco de Portugal*.[16] It consists of a wealth of economic and financial information on virtually all private non-financial firms in the country, including but not limited to location, financial balance sheet indicators, number of employees, and size. This extensive dataset comprises all private firms with activity in Portugal during the period of 2006 to 2019. The firms' participation in the underlying surveys is mandatory and non-compliance is penalized.[17]

We focus on the 339,150 unique firms that exist in 2010 and follow them before (possibly since 2006) and after (possibly until 2019) the shock. Thereby we avoid possible confounding effects from firms that exited before the treatment set in, or firms that entered after the treatment only.[18]

This unique micro dataset allows us to perform an in-depth analysis of the effects of a sharp and unexpected increase in transportation costs on different firm-level performance indicators and a careful analysis of firm-level adaptation measures as outlined in Section 3. Table 1 presents the descriptive statistics for the key variables in the full sample period, while the definitions of all variables are detailed in Table A.1 in the Appendix.[19]

In Section 5, we consider three key indicators of firm performance. Turnover is defined as the amount of sales of goods and services after any allowances, discounts, and returns are considered. Our measure of profitability – EBT or taxable income – is defined as earnings before taxes, but after interest payments, depreciation, and amortisation. Labor productivity is measured as sales revenues divided by workers.

In Section 6, we investigate different dimensions of firm behavior in response to the transportation cost shock. We start by assessing whether firm expenses changed after the shock. Moreover, we analyze the costs associated with goods purchased and material consumed, and with the supplies of external services. We also analyze the consequences of the transportation cost shock for firms' employees investigating changes of (full- and part-time) employment and average wages in response to the shock.

We then examine how domestic turnover and international trade were affected by the increase in highway tolls. We distinguish between the turnover destined to the domestic market and exports, separating those from the European Union (EU) and the rest of the world. This rich dataset further allows us to study changes in inventory and whether entrepreneurs decide to exit from the market in response to the increased costs.

We combine the firm-level information with the road distance to the closest SCUT highway ramp, computed using the 2010 road network grid as provided in Rocha et al. (2022). This is undertaken through *BPLim – Banco de Portugal*, which uses the precise geolocation of each individual firm, at the postal code level. There are 120,925 7-digit postal codes in mainland Portugal. Due to anonymity reasons, we do not have access to the postal codes directly, only to the distances from each postal code centroid to the closest SCUT highway ramp, measured in km.

In the robustness section, we complement the firm-level data with annual administrative municipal-level information, for all the 278 mainland municipalities, which allows us to control for time-variant covariates. These comprise a proxy for agglomeration (population density) as well as two proxies for municipal wealth (mean value of traded real estates and withdrawals on automated teller machines per capita) and total municipal expenditures. Data on agglomeration was retrieved from Statistics Portugal, municipal wealth indicators were retrieved from SIBS company and Statistics Portugal, and administrative data on town hall expenditures was acquired from *Direção Geral das Autarquias Locais (DGAL)*.[20] Table A.3 in the Appendix presents the municipal-level descriptive statistics.

4.2. Empirical strategy

The validity of our strategy relies on the fact that the introduction of tolls on SCUT highways was forced by an exogenous shock (the Sovereign debt crisis) upon the Portuguese political authorities. Being a national matter, municipal authorities played no role in this decision

[16] The data in this database is collected through Simplified Business Information *(IES - Informação Estatística Simplificada)* since 2006. *IES* is an annual report that must be filled online by firms. The quality of this data is then monitored by Statistics Portugal who check with respondents on a regular basis. Researchers can access the dataset in https://bplim.bportugal.pt/

[17] Only firms in mainland Portugal are considered, hence corporations from Madeira and Azores are not part of the analysis.

[18] Note that not all firms have observations for all the years in this period.

[19] For anonymity reasons, we are only allowed to show the mean and standard deviation but not the maximum and minimum values.

[20] SIBS data was used in recent papers such as dos Santos et al. (2021) and Carvalho et al. (2022).

nor were they able to directly intervene.[21] At the same time, there was no discrimination nor favoritism towards particular regions.[22]

We estimate the effect of an increase in transportation costs on outcome y using the following difference-in-differences specification for unit of analysis firm f, in municipality m, in NUTS 2 region n, and year t, during the period 2006–2019, according to:

$$y_{fmnt} = \alpha_f + \lambda_{nt} + \gamma Treated_f \times PostPeriod_t + \epsilon_{fmnt} \quad (1)$$

where α_f denotes firm fixed effects and λ_{nt} represents NUTS 2- year fixed effects.[23] The coefficient of interest is γ, which gives us the treatment effect. Robust standard errors are clustered at the municipal-level (in 2010) to correct for heteroskedasticity and autocorrelation (Bertrand et al., 2004).

Outcome variables y, discussed above, can either be integers, shares, or binary indicators. In the case of integers and shares, we use the inverse hyperbolic sine transformation, a technique which approximates the natural logarithm of the variable, but presents an important advantage as it allows retaining zero or negative-valued observations (Bellemare and Wichman, 2020).[24] When the outcome variable is a binary variable, we compute a linear probability model.

We define treated firms as those that are closer to a segment of the SCUT highway network, namely in the first quintile of the distance to these infrastructures (on average, 3.4 km from the postal code centroid until the closest SCUT highway ramp, and at most 6.2 km).[25] The $Treated$ variable thus takes the value one for firms in the treatment group and zero for all other firms.[26] The balance table Table A.4 in the Appendix shows that there are no statistically significant differences in the pre-treatment (2006–2010) averages of all the main variables in the treatment and comparison groups. We show the geographical distribution according to our treatment definition in Fig. 1.

We define $PostPeriod$ as a binary indicator that equals one from 2011 onwards. It is important to highlight that, in some SCUT highways, tolls were introduced on the 15th of October 2010 while in others, the rise of tolls occured on the 8th of December 2011. Recent developments in the difference-in-differences literature discuss challenges in designs that exploit staggered treatments (Goodman-Bacon, 2021; De Chaisemartin and d'Haultfoeuille, 2020; Athey and Imbens, 2022). However, the no-anticipation of effects assumption discussed, inter alia, by Callaway and Sant'Anna (2021); Borusyak et al. (2021); Roth et al. (2022) is clearly violated in the Portuguese case, precluding us from exploiting staggered effects, as agents understood, when the first set of tolls were implemented, that the remaining toll-free highways would also be treated – and therefore, they possibly reacted before the second wave of tolls. In fact, several news articles document that the Government announced well in advance the new second round of tolls.[27]

[21] Even though there were huge protests made by SCUT highway users and local mayors, they had no saying in this decision. (See https://www.jornaldenegocios.pt/empresas/transportes/detalhe/municipios_e_utentes_perdem_accoes_contra_portagens).

[22] Audretsch et al. (2020) point out that there was no political attempt to favor municipalities aligned with the parties in central government.

[23] Gabriel et al. (2022) show that the allocation of European funds is important for business firms dynamics in Portugal. Since this allocation is done at the NUTS2-level, using regional-year fixed effects can help accounting for this effect.

[24] In the robustness section, we show that the effects are robust to a logarithm specification or in levels.

[25] Audretsch et al. (2020) and Pereira et al. (2021) use a similar identification strategy, but both identify treatment at the municipal-level. A previous version of this paper also used this definition and results were very similar.

[26] In the robustness section, we show that the effects are robust to using other definitions of the treatment, including the first sixtile or the first quartile of distance.

[27] See, for example, https://www.publico.pt/2010/06/30/politica/noticia/governo-propoe-portagens-nas-outras-scuts-a-partir-de-2011-1444581.

The internal validity of a difference-in-differences estimation model relies on the parallel trends' assumption (Angrist and Pischke, 2008). This assumption states that in absence of treatment, the average outcome of the treatment group would have changed with a similar trend as the average outcome of the comparison group. For a careful test on the validity of the parallel trends' assumption, we rely on event study designs for the main outcome variables. An event study has two main advantages. First, it allows us to observe whether the strength of the treatment varies with time. Second, it provides a more rigorous test on whether the common trend assumption holds in the pre-treatment periods (i.e., 2006–2009 in our sample). The estimating equation for the event study of firm f, in municipality m, NUTS 2 region n, and year t is:

$$y_{fmnt} = \alpha_f + \lambda_{nt} + \sum_{t=2006}^{2009} \psi_t Treated_f \cdot Year_t + \sum_{t=2011}^{2019} \psi_t Treated_f \cdot Year_t + \epsilon_{fmnt} \quad (2)$$

and all variables are defined as before. The coefficients of interest are ψ, capturing the dynamic effects of the treatment, before and after the introduction of tolls in SCUT highways. Notice that in Eq. (2) all interactions are included, except for 2010. This way, all the coefficients are estimated in relative terms to that year.

4.3. Heterogeneity

We exploit the heterogeneity in our sample to shed light on the potential mechanisms driving our results. We divide the universe of Portuguese private firms between tradables and non-tradables sectors, as defined in Amador and Soares (2012) and Gouveia and Canas (2016). In principle, firms in tradables sectors may be more strongly affected by the tolls than firms in non-tradables s as they tend to be, on average, more reliant on transportation.

We also run triple difference-in-differences specifications accouting for pre-treatment labor productivity. More specifically, we compare the least productive firms (first quintile of the distribution in 2010) and the most productive firms (fifth quintile of the distribution in 2010) with the remaining firms (second to fourth quartiles).

4.4. Identification threats and robustness

We perform a battery of difference-in-differences robustness checks – the results of which will be discussed in Section 7 – to assure the reliability of our results. First, in our baseline estimates, we define treated firms to be those in the first quintile of distances to SCUT highway ramps. We relax this assumption by considering either a larger set of treated firms (in the first quartile of distance – on average 4.1 km and at most 8.1 km) or a smaller set of treated firms (in the first sixtile of distance – on average 2.95 km and at most 5.2 km). Note that Portugal is a small country and SCUT highways cover a significant portion of the territory. Therefore, it is not surprising that distances in these two alternatives are not so different from distances in the baseline (on average 3.4 km and at most 6.2 km).

Second, classical difference-in-differences regressions can produce biased estimates for the average treatment effect if treatment crosses to border regions (Butts, 2021). For this reason, we perform a robustness test adding one ring to our baseline interaction coefficient (i.e, the second quintile of distance to SCUT highways – on average 13 km and at most 24.5 km). If the second coefficient is non-statistically significant while the first remains its significance, this indicates that treatment effects are concentrated in the treated area and do not contaminate neighboring areas to a significant degree.

Third, we modify our econometric specification to include more demanding fixed effects and a vector of municipal-level controls. One important threat to our identification strategy arises if there are other

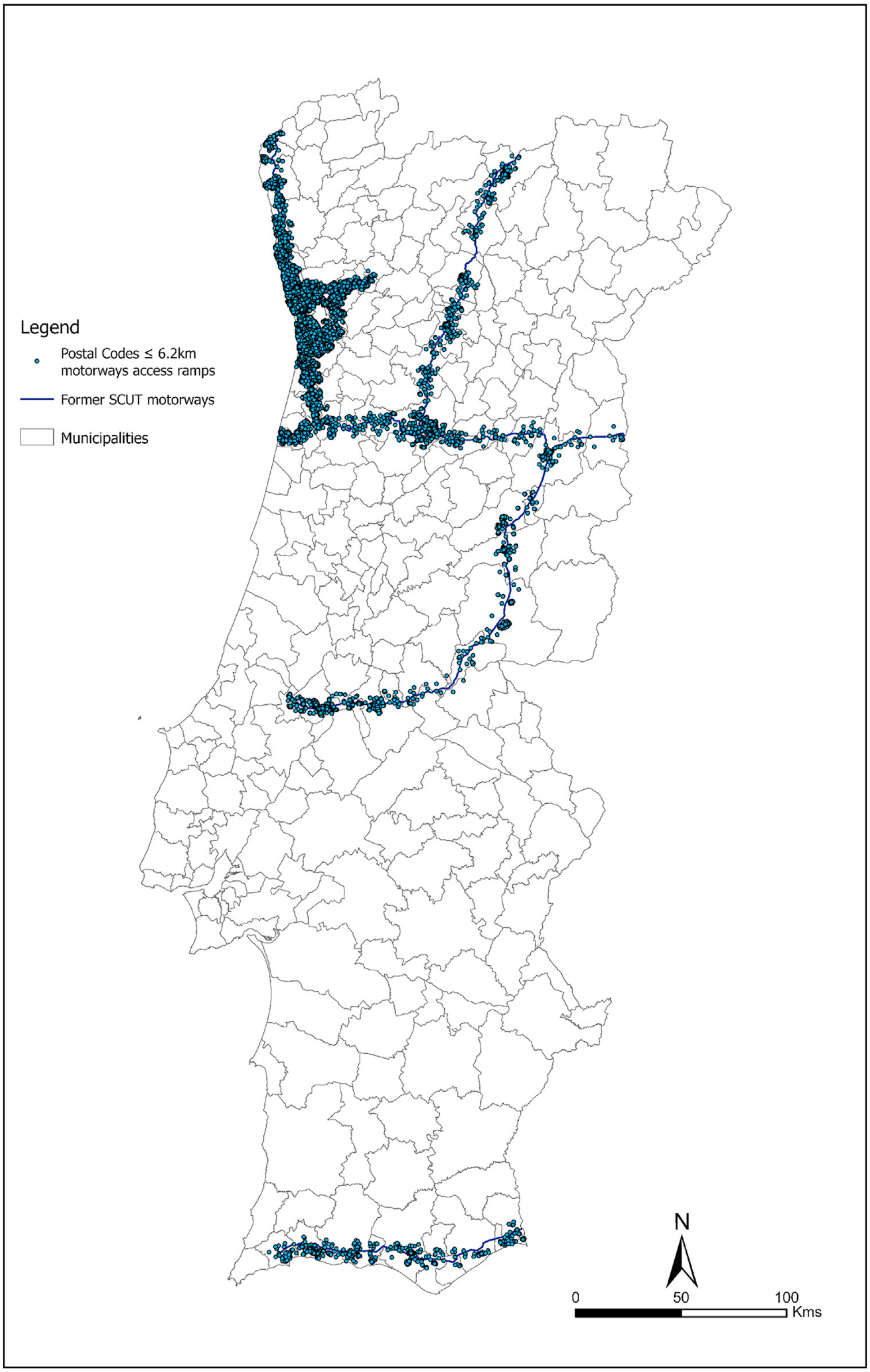

Fig. 1. Treatment and comparison areas.
Notes: The definition of the treatment area comprises 20% of the firms that are closest to a SCUT highway ramp measuring location at the 7-digit postal codes centroids. For the spatial distribution of SCUT and non-SCUT highways see Fig. A.1 in the Appendix.

contemporaneous shocks than the treatment that occur during the time period under analysis. Our time period includes the European Financial Crisis, which forced the Portuguese government to request international financial assistance. Given that this crisis might have had heterogeneous effects, depending on the geography, we test whether our baseline results hold if we substitute NUTS 2- year fixed effects (5 regions) by NUTS 3- year fixed effects (25 regions). On top of this, in some specifications, we also include a vector of municipal-level yearly controls, discussed above, to further take into account potential differences in the economic development context of these regions.[28] In addition, we also challenge our baseline results by adding NUTS 2- year fixed effects, and sector of activity- year fixed effects. Note that this is an extremely demanding

[28] We acknowledge that controlling for municipal level covariates could also be problematic, as they can also respond to the treatment (Sant'Anna and Zhao, 2020). Nevertheless, the results are remarkably similar with and without these controls.

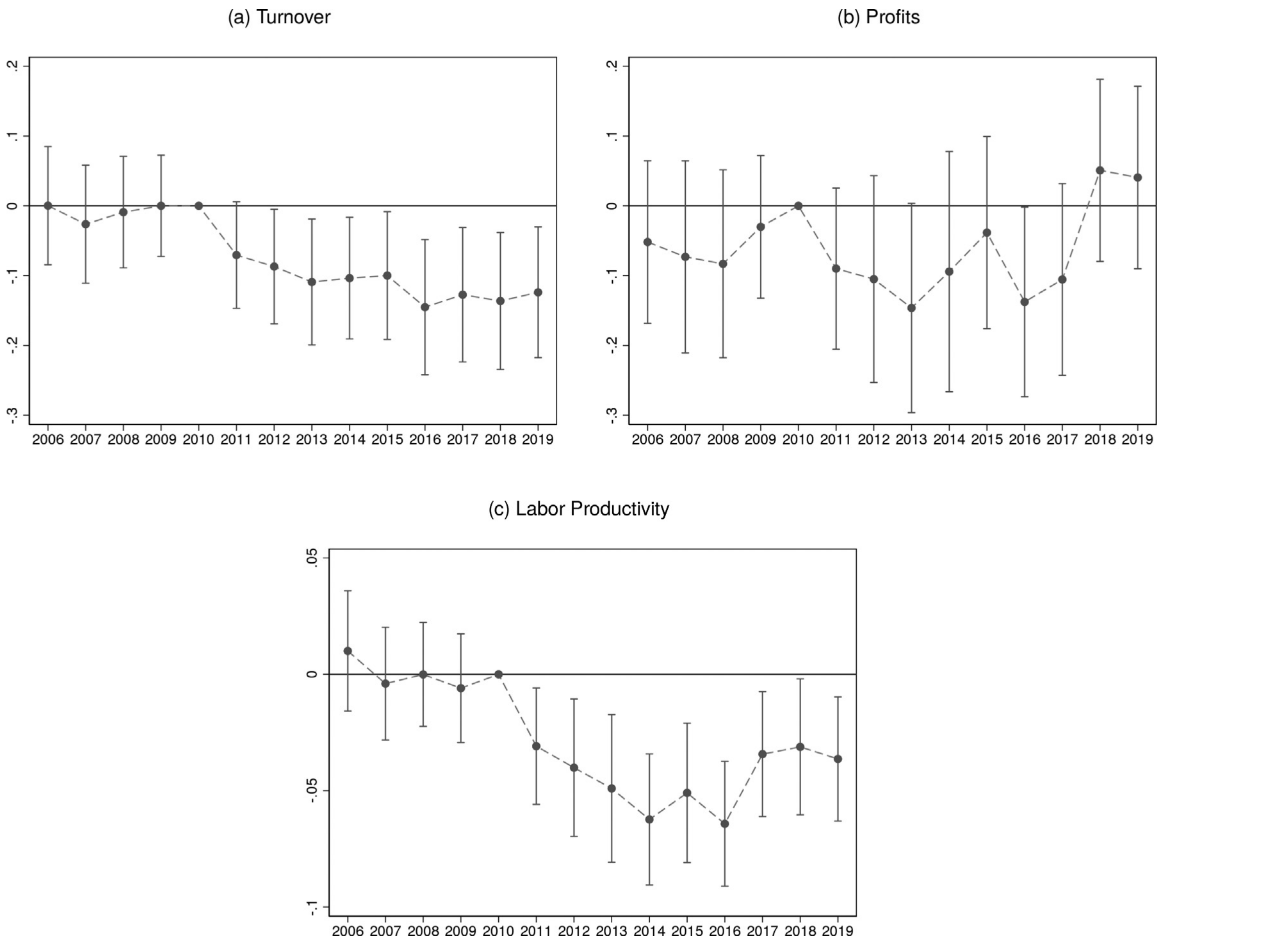

Fig. 2. Event studies – firm performance.
Notes: The first two variables are measured using the inverse hyperbolic sine transformation. Graphs were computed with Firm and NUTS 2 × Year fixed effects. The 90% confidence levels are calculated using clustered standard errors at the municipal level.

specification as we use 5-digit sector of activity classifications comprising 816 groups.

Fourth, we run a horse race between our treatment difference-in-difference effect of distance to nearest Scut highways and the first quintile of distance to all other (Non-SCUT) highways. In theory, even though all these alternatives were already available at the beginning of our sample period, some firms might potentially mitigate the negative effects of the shock by increasing the use these infrastructures. Furthemore, as can be seen in Fig. A.1 in the Appendix, the only treated firms that find alternative (Non-Scut) highways in acceptable distance are those in the coastal Northwest of Portugal. Therefore, as a further robustness check we restrict our analysis to firms in the four districts in the northwest corner (Viana do Castelo, Braga, Porto, and Aveiro) where alternative non-SCUT highways are available.

Fifth, we show that our results are robust to the exclusion of certain groups of firms. We start by analyzing only single-establishment firms, which constitute the large majority of our sample excluding some very big firms. We then show that dropping firms in the 18 municipalities that are district capitals, i.e., more urban areas that are important poles of attraction at the regional level, and removing all firms in the Lisbon NUTS 3 area does not challenge our conclusions.[29] We also include an analysis with the dependent variables winsorized at 90% and a balanced sample, considering only firms that remain in our dataset from 2006 to 2019.

Finally, for the main dependent variables in levels that are computed using the inverse hyperbolic sine transformation, we show that results are similar when we use the logarithmic transformation adding a small positive number. Recent contributions by Mullahy and Norton (2022) and Chen and Roth (2022), however, showed that both approaches may raise concerns, especially if the outcome variables have a significant share of zeros (which is not the case for the considered outcomes, with the exception of exports). In any case, we run the OLS difference-in-differences in levels, as suggested by these econometricians.

5. Firm performance

5.1. Baseline results

We present the event study estimates for three key measures of firm performance, computed as in Eq. (2), in Fig. 2: firm turnover (in panel a), Earnings before taxes, a proxy for profits (in panel b), and labor productivity (in panel c). For all these indicators, our results corroborate the parallel trends assumption, suggesting that there are no significant differences between the treatment and the comparison group in the years 2006–2009 before the treatment set in.

We find that treated firms (i.e. firms in the first quintile of distance to the SCUT-highways) when compared with firms in comparison areas, experienced a significant reduction in their turnover, which is still persistent after nine years. Interestingly, this did not translate into lower

[29] In 2003, the Portuguese municipalities were allowed to organize themselves into inter-municipal communities and the two metropolitan areas of Lisbon and Porto. Since then, administrative, financial, and political competencies have been transferred to these entities. Districts in mainland Portugal still serve as a basis for electoral constituencies.

Table 2
Firm performance deteriorated with the introduction of tolls.

	Total revenues	Turnover	Services	Profits	Net income	Labor productivity
	(1)	(2)	(3)	(4)	(5)	(6)
$Treated \times Post$	−0.105***	−0.102***	−0.102***	−0.041	−0.045	−0.043***
	(0.038)	(0.037)	(0.034)	(0.078)	(0.071)	(0.013)
Firm FE	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y
$N \times T$	3,753,863	3,753,863	3,753,863	3,753,757	3,753,755	2,812,764
R^2	0.680	0.688	0.767	0.415	0.402	0.597

Notes: Profits are proxied using earnings before taxes. Standard errors in parenthesis are clustered at the municipal level. Outcome variables are measured using the inverse hyperbolic sine transformation. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table 3
Heterogeneity: performance indicators - non-tradables vs. tradables.

	Turnover		Profits		Labor productivity	
	NT	T	NT	T	NT	T
$Treated \times Post$	−0.068*	−0.185***	0.055	−0.251**	−0.034***	−0.055***
	(0.039)	(0.044)	(0.080)	(0.106)	(0.012)	(0.018)
Firm FE	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y
$N \times T$	2,729,479	1,022,579	2,729,425	1,022,528	2,010,327	800,622
R^2	0.685	0.710	0.423	0.400	0.604	0.587

Notes: Standard errors in parenthesis are clustered at the municipal level. All variables are measured using the inverse hyperbolic sine transformation. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

profits. Profits were noisier in the treatment period and significantly went down in one year (2016), but are non-significant in all other years. At the same time, labor productivity decreased in treated areas after the transportation shock, and until 2016. After that, we observe a modest recovery, although labor productivity in the most recent years (2017–2019) is still significantly lower than in the pre-treatment years.

The event study results are confirmed in the difference-in-differences specifications, estimated using Eq. (1), and presented in Table 2.

As shown in columns (1) and (2), we find that treated firms experienced, on average, a decrease of 10.2% in turnover (10.5% in total revenues) *vis-à-vis* firms located in comparison regions.[30] Importantly, the considerable decrease in turnover is not only due to the higher costs for the transport of manufactured goods. As shown in column (3), sales of services, which account for about 25% of turnover, on average, fall in a similar order of magnitude as turnover (total sales). This finding suggests that increased commuting and travel costs for consumers of services also played a sizeable role in decreasing output.

For profits, we find that earnings before taxes, in column (4), reduced by 4.1%, on average. However, the results are not precisely estimated and the effect is not statistically significant. Considering another proxy for profits: net income (i.e., earnings after taxes), in column (5) leads to a similar result. Finally, we observe a reduction in labor productivity of 4.3%, on average, in column (6), a result which is statistically significant.

Overall, we find that the tolls led to long-term decreases in firm output (turnover) and in labor productivity. However, there were no significant effects on firm profits, suggesting that firms might have been able to pass through part of the burden of the tolls to other economic actors. Our findings are in line with related research on the output and productivity effects of infrastructure provision. The strength of effects is a bit higher than what is usually found for OECD countries (see, for instance, Holl (2016) or Gibbons et al. (2019)), but clearly lower than what has been found for developing countries (e.g. Fan et al. (2019) and Ghani et al. (2016)).

5.2. Effect heterogeneity

We first test whether results differ with respect to the sector of activity. To do so, we run our results separately for firms in the non-tradables and in tradables sectors. The results for the main firm performance indicators are shown in Table 3. As can be seen, tradables sectors are more strongly affected by the tolls than non-tradables sectors, although the negative effects of the tolls on turnover and productivity remain significant in the non-tradable sectors as well. Importantly, we find evidence that profits decreased considerably for firms in tradables sectors, but not in the non-tradables.

Second, we carefully examine whether firm-specific productivity makes a difference in the way that firms are affected by the transportation shock using triple difference-in-differences specifications. We define the least productive firms as those in the first quintile of labor productivity in the pre-treatment year while the most productive firms are those in the fifth quintile of labor productivity measured in the same period. We then compare the effects for these firms, in the post-treatment period and in treated areas, relative to firms in the middle of the distribution of labor productivity (second, third, and fourth quintiles). In each specification, we drop firms in the quintile that is not being considered.

Results for the three main firm performance variables are presented in Table AH.1 in the Appendix. We observe that high productivity firms (LP_{Q5}) are not differently affected by the shock than the firms in the middle of the labor productivity distribution. However, low productivity firms (LP_{Q1}) seem to suffer more as they face a sharper decrease in turnover.

6. Firm behavior

The majority of research on the firm-level effects of infrastructure looks at single performance indicators and remains silent with respect to the various adaptation measures that firms have at their disposal. To

[30] As sales of goods and services are the main source of firms revenues, it is plausible that both variables are affected in a similar order of magnitude.

Table 4
Firm expenses and labor adjusted to the introduction of tolls.

	Expenses	Materials	Services	Employee	FT workers	PT workers	Av Wages
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Treated \times Post$	−0.079**	−0.095***	−0.083***	−0.065*	−0.016**	0.002	−0.020***
	(0.031)	(0.032)	(0.031)	(0.035)	(0.006)	(0.003)	(0.005)
Firm FE	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y	Y
$N \times T$	3,753,863	3,753,863	3,753,863	3,753,863	3,337,876	2,246,598	2,812,764
R^2	0.699	0.816	0.703	0.748	0.853	0.684	0.631

Notes: Standard errors in parenthesis are clustered at the municipal level. All variables are measured using the inverse hyperbolic sine transformation. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

better understand the mechanisms by which firms actually adapt to a massive transportation cost shock we carefully analyze different kinds of adaptation measures in this section.

In order to stay competitive and not lose too many customers, a possible behavioral response is that firms try to cut their other non-transport related expenditures, which include inputs of goods and services as well as labor costs. Firms could try to shift the burden of the highway tolls – at least partly – to their suppliers or employees. We thus study the development of firm expenses after the shock, giving particular attention to the purchase of goods and services input (in Section 6.1) and to the evolution of labor costs in terms of employment numbers and wages (in Section 6.2). Another way in which firms could adapt to the transportation cost shock is changing their sales strategy by focusing on sales markets in which the transport cost increase on domestic (SCUT-) highways plays a lesser role. Therefore, we separately analyze how the tolls have affected firms' domestic sales, their exports to the EU, and their exports to the rest of the world (in Section 6.3). Changing inventory is a further possible adaptation measure that has gained some prominence in the literature. Moreover, some firms might decide to leave the market as a reaction to the transportation cost shock. Such a strong reaction is unlikely for the majority of firms, but it might be plausible for firms that are particularly affected (e.g. firms that are particularly dependent on transportation) or particularly vulnerable (e.g. under-performers with particularly low productivity). Both modes of adaptation are investigated in Section 6.4. Section 6.5 investigates effect heterogeneity, and Section 6.6 summarizes how firms adapted to the shock.

6.1. Expenses

We first focus on how firms adjusted their expenses in reaction to the shock using the event study strategy described in Eq. (2). The results are exhibited in Fig. 3. Once again, we find evidence suggesting that the parallel trends assumption holds in this setting. In addition, we observe that expenses were significantly reduced after the introduction of tolls. Although expenses decreased immediately after the shock, the decrease was not significant in the first years. This suggests that firms needed some time to adapt to the new situation and find a new (lower) equilibrium level of expenses.

The difference-in-differences results, displayed in column (1) of Table 4, confirm that total expenses in treated firms decreased by, on average, 7.9%. Importantly, the level of detail in the dataset allows us to divide expenses in several categories. We find that firms significantly reduced their expenditure for purchases of goods and materials consumed (in column 2) as well as their purchases of supplies and external services (in column 3). These findings suggest that firms passed through part of the burden of the tolls to their suppliers. Moreover, they imply that the cost cutting did not only hit the suppliers of manufactured input goods and materials but also the suppliers of service inputs.

Apart from cutting goods and services inputs, labor cost cutting is another obvious candidate for adaptation under economic pressure. We find that employee-related expenses (which apart from the wage bill also include social security and insurance payments) decreased by 6.5%

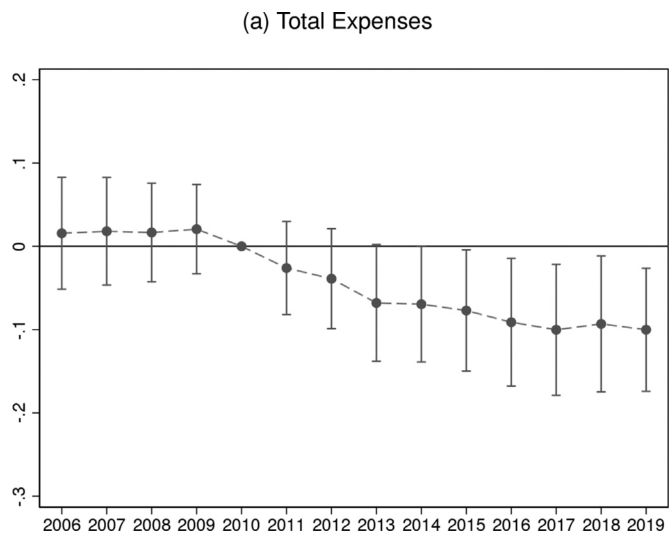

Fig. 3. Event studies – expenses.
Notes: The variable is measured using the inverse hyperbolic sine transformation. Graph computed with Firm and NUTS 2- Year fixed effects. The 90% confidence levels are calculated using clustered standard errors at the municipal level.

(in column 4). The precise mechanisms are further investigated in the next sub-section.

6.2. How firms cut labor costs: employment reduction versus wage reduction

We now look into the consequences of the tolls for firms' employees. We distinguish between the effects on full- and part-time employment and on average wages. We present the event study results, estimated using Eq. (2), for labor related outcomes in Fig. 4. We detect that the introduction of tolls had a significantly negative effect on the number of full-time workers (in panel a). Importantly, these effects seem to deteriorate further between 2013 and 2019.

We next provide the event study specifications of averages wages (in panel b). We find a significant negative impact of the tolls on average wages which seems to further deteriorate over time, suggesting that both channels (reduction of employment and lower wages) play a significant role in cutting labor costs and adapting to the transportation cost shock.

The difference-in-differences results, computed as in Eq. (1), are presented in Table 4 and confirm the event study insights. We find a significant reduction of full-time paid employment of 1.6% on average, for treated firms *vis-à-vis* firms in the comparison group (in column 5).[31]

[31] These results are consistent with the findings of Audretsch et al. (2020), who documented a significantly negative impact on employment at the municipal-level.

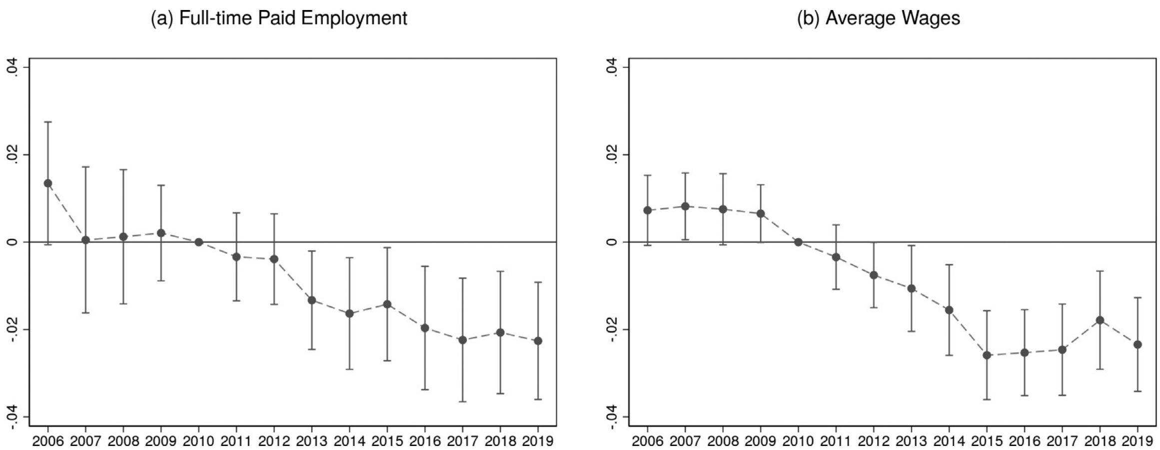

Fig. 4. Event studies – labor market.
Notes: The two variables are measured using the inverse hyperbolic sine transformation. Graphs were computed with Firm and NUTS 2 × Year fixed effects. The 90% confidence levels are calculated using clustered standard errors at the municipal level.

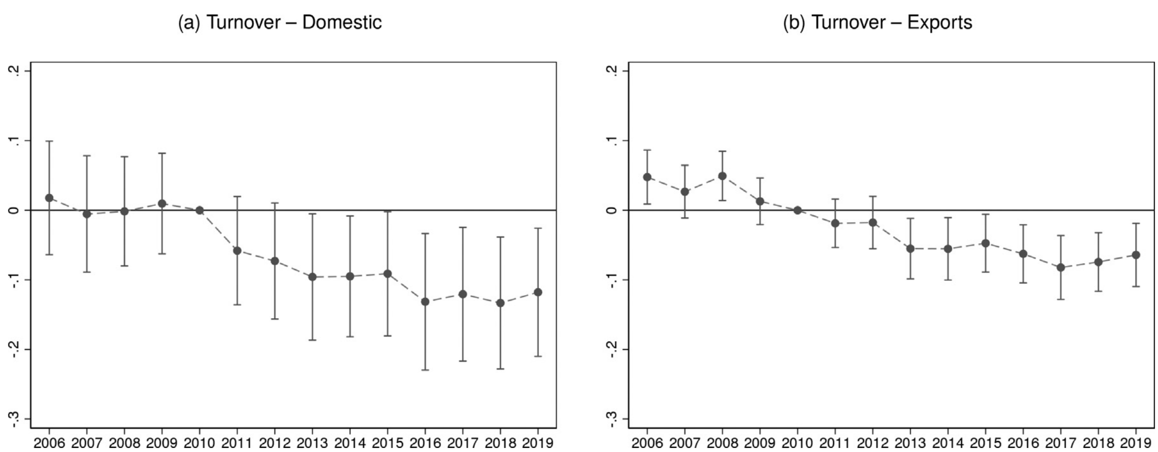

Fig. 5. Event studies – turnover by destination.
Notes: Outcome variables are measured using the inverse hyperbolic sine transformation. Graph computed with Firm and NUTS 2 × Year fixed effects. The 90% confidence levels are calculated using clustered standard errors at the municipal level.

Employers do not seem to switch to part-time employment (in column 6). At the same time, average wages decreased by 2% (in column 7).

It cannot be excluded, however, that part of the decrease in average wages is driven by a change in the structure of employment in treated firms. A decreasing number of full-time employees and a constant number of part-time employees imply an increasing share of part-time employment which in turn drives down average wages. This latter interpretation is in line with earlier research showing that there is a strong downward nominal wage rigidity in Portugal (Dias et al., 2013), and that legal restrictions on nominal wage cuts and periods of close-to-zero inflation leave employers with limited margin to adjust real wages, such that, in periods of crisis, employment is the main margin of adjustments (Carneiro et al., 2014).[32]

Our finding that highway tolls affect both employment and wages – even if part of the decrease in average wages is driven by the decrease in full-time employment – is in line with the conclusions of recent research by Herzog (2021) who finds that the US Interstate Highway System affected both employment and (to a somewhat lesser extent) wages.

6.3. Destination of trade: which markets are affected?

Another way in which firms could adapt to the transportation cost shock is changing their sales strategy by focusing on sales markets in which the transport cost increase on domestic (SCUT-) highways plays a lesser role. Therefore, we separately analyze how the tolls have affected firms' domestic sales, their exports to the EU, and their exports to the rest of the world.

The event study findings of estimating Eq. (2) are presented in Fig. 5 for domestic turnover (in panel a) and exports (in panel b). Our results show an increasing deterioration with persistent effects for treated firms, concerning both outcomes, domestic turnover and exports. Results for exports should be interpreted with a grain of salt, however, since the parallel trends' assumption does not hold in this case (Roth, 2022).

We enhance the analysis by computing difference-in-differences regressions as in Eq. (1). Our findings are displayed in Table 5. In column (1), we analyze the impact of the transportation shock on turnover that is sold in the domestic market. We find that firms subject to this shock experienced a decrease in turnover from the internal market by 10%, an effect that is similar to the decrease in total turnover.

We next focus on the extensive and intensive margins of selling abroad. Our results clearly suggest that the introduction of tolls had

[32] The nominal minimum wage was frozen between 2011 and 2014 at 485 euros (Alexandre et al., 2022).

Table 5
Other behavioral measures were also affected by the introduction of tolls.

	Domestic	Prob exporting	Exports	Exports EU	Exports non-EU	Inventory	Prob exit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Treated \times Post$	−0.100***	−0.006***	−0.069***	−0.076***	−0.000	0.006	0.006**
	(0.036)	(0.002)	(0.022)	(0.019)	(0.014)	(0.032)	(0.002)
Firm FE	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y	Y
$N \times T$	3,753,863	3,753,863	3,753,863	3,753,863	3,753,863	3,753,863	4,871,327
R^2	0.683	0.635	0.709	0.707	0.651	0.815	0.390

Notes: Standard errors in parenthesis are clustered at the municipal level. All variables, with the exception of the Prob of exporting and the Prob of exit, are measured using the inverse hyperbolic sine transformation. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

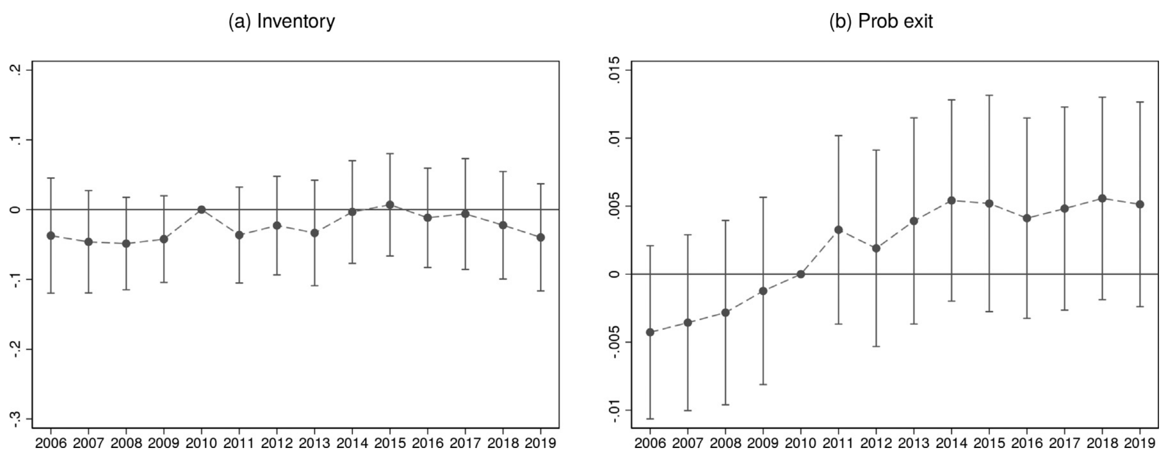

Fig. 6. Event studies – other mechanisms.
Notes: Inventory is measured using the inverse hyperbolic sine transformation. Graphs computed with Firm and NUTS 2 × Year fixed effects. The 90% confidence levels are calculated using clustered standard errors at the municipal level.

a marginal impact of less than 1% on the probability of firms to sell abroad (in column 2). The effects are much larger for the intensive margin, however, showing that the exports of treated firms decreased by 6.9% (in column 3) relative to more distant firms from SCUT highways.

Finally, we go one step further to separately analyze the exports destined to the EU market and the ones destined to the rest of the world.[33] One can see that exports to the EU area in column (4) were significantly reduced (−7.6%), while no significant effect was found for the ones directed to the non-EU market in column (5). The stronger reduction of domestic turnover and exports destined to the EU appears plausible as these two markets depend strongly on road transportation. It is also in line with the findings of related research by Fan et al. (2019) who find that the effect of highway infrastructure on domestic trade is stronger than the effect on foreign trade (exports).

Regarding the EU market, it is important to highlight that Spain is one of the main trading partners of Portugal[34] and Portugal's gate to the rest of the EU. Some of the affected highways are the most important roads to Spain, and Spain's proximity to Portugal makes trade between these two countries particularly dependent on road transportation. By contrast, a large part of Portugal's exports to the "rest of the world" is transferred by ship and thus relatively less dependent on road transport than Portugal's trade with the EU. In other words: export destinations outside the EU are less affected by the tolls and becomes more attractive for the treated firms – at least in relative terms – than destinations within Portugal and within the EU.

6.4. Other mechanisms: changes in inventory and exit

A change of inventory is a further possible adaptation measure. Firms might build up inventory in order to reduce the number of trips and save transportation costs. In the empirical literature there is evidence for a decrease in inventory following the provision of rail or road infrastructure (Shirley and Winston, 2004; Datta, 2012; Li and Li, 2013). One might argue that a road price shock works in the opposite direction and could thus lead to an increase in inventory. We inspect this possibility in this subsection.

We measure inventory in monetary terms and exhibit the event study results in Fig. 6 (panel a). The results convey that the introduction of tolls in SCUT highways had no significant effects on inventory. The difference-in-difference results are presented in column (6) of Table 5 and confirm the event study results: firms did not seem to change their inventories in response to the transportation cost shock. A possible explanation for this non-finding is that building up new inventory is not the same as reducing inventory. Reducing inventory is relatively cheap and easy, whereas building up new inventory often requires investment (for example, in real estate) which might be prohibitively expensive.

Finally, we turn to the strongest possible firm-level reaction to a price shock which is exiting the market.[35] As can be seen from the event study

[33] Bastos et al. (2018) show that exporting to richer countries leads Portuguese firms to pay higher prices for inputs, raising the average quality of goods they produce.

[34] In 2010, Portugal's exports to Spain accounted for 32% of the total exports made to the EU area.

[35] In the analysis so far we have only considered firms that were active in 2010, i.e. at the time when the tolls were implemented. For an adequate analysis of exit it is necessary, however, to consider exit in the pre-treatment years as well.

Table 6
Heterogeneity: behavior indicators - non-tradables vs. tradables.

	Expenses		Av wages		Full-time workers		Inventory		Prob exit	
	NT	T	NT	T	NT	T	NT	T	NT	T
$Treated \times Post$	−0.048	−0.146***	−0.016***	−0.027***	−0.008	−0.032***	0.004	0.043	0.005*	0.009***
	(0.034)	(0.034)	(0.005)	(0.007)	(0.006)	(0.009)	(0.035)	(0.039)	(0.003)	(0.002)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
$N \times T$	2,729,479	1,022,579	2,010,327	800,622	2,413,395	922,487	2,729,479	1,022,579	3,523,558	1,343,936
R^2	0.693	0.727	0.625	0.648	0.842	0.877	0.809	0.836	0.385	0.409

Notes: Standard errors in parenthesis are clustered at the municipal level. All variables, with the exception of probability of exit, are measured using the inverse hyperbolic sine transformation. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table 7
Robustness: Turnover – Part I.

	Turnover (ihs)							
	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Treated \times Post$	−0.102***			−0.104**	−0.101**	−0.101**	−0.106***	−0.100***
	(0.037)			(0.050)	(0.039)	(0.041)	(0.039)	(0.036)
$Quartile \times Post$		−0.082**						
		(0.040)						
$Sixtile \times Post$			−0.084**					
			(0.042)					
$Ring \times Post$				−0.003				
				(0.047)				
$NoSCUT \times Post$								−0.045
								(0.062)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	N	N	Y	Y
NUTS 3– Year FE	N	N	N	N	Y	Y	N	N
Controls	N	N	N	N	N	Y	N	N
Sector– Year FE	N	N	N	N	N	N	Y	N
$N \times T$	3,753,863	3,753,863	3,753,863	3,753,863	3,753,863	3,753,863	3,753,479	3,753,863
R^2	0.688	0.688	0.688	0.688	0.688	0.688	0.695	0.688

Notes: Standard errors in parenthesis are clustered at the municipal level. Nuts 2 (3) comprises 5 (25) groups of regions. The vector of annual municipal-level controls comprises Population density, Withdrawals on ATMs (automated teller machines) per capita, Mean value of traded real estates, and Municipal expenditures per capita. Sector comprises 816 groups of 5-digit sectors of activity. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

graph in Fig. 6 (panel b), point estimates in the treatment period are all positive and pointing towards a small effect on exit of close to 0.5%. These effects are, however, not statistically significant.[36]

The results of the difference-in-differences strategy, presented in column (7) of Table 5, point towards a very small positive effect of about 0.5%, on average, and statistically significant (at 5% confidence level). In any case, the effects on exit for the full sample of firms appear to be rather small. However, for certain groups of firms, we observe stronger effects on exit. This will be discussed in the next subsection.

6.5. Effect heterogeneity

We next investigate possible effect heterogeneity on the main adaptation measures by dividing our sample between firms in the tradables and non-tradables sectors, as shown in Table 6. In all cases (except for inventory), point estimates show that firms in tradables sectors reacted more strongly to the deterioration of the economic situation induced by the introduction of tolls. This is in line with the findings from Section 5, indicating a particular strong decrease in turnover in tradables sectors.

Lastly, we examine whether firm-specific productivity makes a difference in the way that firms adapt to the transportation cost shock using a triple difference-in-differences with the least and the most productive firms in Table AH.2 in the Appendix. We observe that high productivity firms (LP_{Q5}) are not differently affected by the shock than the firms in the middle of the labor productivity distribution. By contrast, we find that low productivity firms (LP_{Q1}) have significantly stronger reactions in terms of reducing expenses, employment, and average wages. Moreover, these firms have a significantly higher probability to exit the market.

6.6. In a nutshell: how firms adapted to the shock

Overall, we find that firms respond to the transportation cost shock with a significant cut of total expenses. This cut affects expenses for goods and materials consumed in a similar order of magnitude as expenses in the purchase of services. Labor costs were cut by reductions of full-time employment as well as by lower average wages. We also observe a shift in the relative importance of different trade destinations: domestic sales and exports to the EU were substantially reduced, whereas exports to the rest of the world were not affected. We do not find a significant effect of the tolls on inventory and only a marginal positive effect on the probability of exit for the full sample of firms. However, firms in tradables sectors and low productivity firms have a clearly higher probability of exit than firms in non-tradables sectors and high productivity firms.

7. Robustness checks

We challenge our baseline results with a plethora of robustness checks as described and motivated in Section 4.4. These checks are so

Without considering exit in the pre-treatment years we would miss a suitable yardstick for comparison of exit probabilities before and after the treatment as well as a suitable test of the common trends assumption.

[36] The parallel trend, even though it is also not statistically significant, seems to be increasing with time and therefore should be interpreted with a grain of salt (Roth, 2022).

Table 8
Robustness: Turnover – Part II.

	Turnover (ihs)						ln(Turnover+1)	Turnover
	Only NW	Single	No DC	No Lisbon	Winsor	Balanced		
Treated × Post	−0.110**	−0.105***	−0.153***	−0.078**	−0.095***	−0.078***	−0.098***	−57703.235*
	(0.046)	(0.037)	(0.044)	(0.036)	(0.036)	(0.028)	(0.035)	(30987.598)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y	Y	Y
$N \times T$	1,289,294	3,631,567	2,622,017	2,510,628	3,753,863	2,157,858	3,753,863	3,753,863
R^2	0.690	0.686	0.691	0.691	0.678	0.721	0.692	0.929

Notes: Standard errors in parenthesis are clustered at the municipal level. No DC removes all firms in district capitals while only NW considers only firms in the four northwestern districts of Viana do Castelo, Braga, Porto, and Aveiro. Winsorization of the outcome variable at the 90th percentile in column (11). Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

comprehensive and voluminous that they cannot all be presented in the main part of the paper. For illustrative purposes, we present the results for turnover in the main text (in Tables 7 and 8) and the respective results for all other key variables in the Appendix to this paper: Profits (in Tables AR.1 and AR.2), labor productivity (in Tables AR.3 and AR.4), expenses (in Tables AR.5 and AR.6), full-time employment (in Tables AR.7 and AR.8), averages wages (in Tables AR.9 and AR.10), inventory (in Tables AR.11 and AR.12), and exit (in Tables AR.13 and AR.14).

We begin by showing that our results do not depend critically on our particular definition of treatment. In fact, if we substitute the first quintile of distance by the first quartile (in column 1 of Part I tables) or by the first sixtile of distance (in column 2), we obtain very similar effects. Moreover, when we add the second to the first quintile (in column 3), as a ring around the treatment area, the effect remains very similar to baseline while the second quintile interaction is not statistically significant (except for labor productivity), suggesting that our definition of treatment is adequate (Butts, 2021). Moreover, our findings, with the exception of probability of exit, are robust to several vectors of fixed effects (NUTS 3- year or Sector-year) and the inclusion of annual municipal-level controls (columns 4 to 6).

Although alternative (non-SCUT) highways in Portugal are tolled as well such that potential cost savings from using alternative highways are limited, we have carefully analyzed whether our findings still hold in the presence of these alternative roads. First, we find that a horse race adding the first quintile distance to non-SCUT highways (in column 7) leaves, once again, point estimates of the treatment effect very similar to baseline, highlighting that even firms that can have reasonable non-SCUT highway alternatives suffered from the shock. Second, Fig. A.1 in the Appendix (highway map of Portugal) makes clear that the only treated firms that have alternative (non-SCUT) highways nearby are those in the coastal Northwest of Portugal. Therefore, as a further robustness check we restrict our analysis to the four districts in the northwestern corner of Portugal where alternative highways are available. Our findings are displayed in the first column of Part II tables ("Only NW") and very much resemble the baseline results. Hence, we conclude that the availability of alternative highways does not change our main results.

The results are also robust in other particular subsamples, as shown in Part II tables: when we consider only single establishment firms, excluding firms that are in the bigger regional cities (district capitals), or when we remove the Lisbon NUTS 3 area. In addition, our baseline conclusions do not change when we consider the influence of outliers by winsorization of the outcome variables at the 90th percentile, use an alternative logarithmic transformation (instead of the inverse hyperbolic sine (ihs) transformation), and when we consider variables in levels in our econometric specification.[37]

8. Conclusion

The current paper contributes to a better understanding of the various firm-level effects and behavioral responses to a massive transportation cost shock. Based on a unique firm-level data set covering virtually the whole universe of private firms in a country and relying on detailed geolocated distance measures, we find that the introduction of tolls on previously free highways led to a long-term decrease in turnover by 10.2% and in labor productivity by 4.3%, whereas profits were not significantly affected. A possible interpretation is that treated firms were able to pass through part of the burden of the tolls to other economic agents.

With respect to firm behavior in response to the shock we find a significant cut of total expenditures. This expenditure cut affects goods and materials consumed in a similar order of magnitude (about 8%) as expenses in the purchase of services. Taking a closer look at the labor market, we find that labor costs were reduced by employment cuts as well as by a decrease of average wages. We also observe a shift in the relative importance of different trade destinations: domestic turnover and exports to the EU declined significantly, whereas exports to the rest of the world were not affected. We consider this a plausible result since domestic turnover and exports to the EU depend heavily on road transport, whereas exports to the rest of the world depend mainly on sea transport. We do not find a significant increase in inventory in response to the tolls which might be explained by the fact that building up new inventory often requires substantial investment (e.g., in real estate) which might be prohibitively expensive. Firm exit, the arguably strongest response to a price shock, does not play a sizable role in the full sample of firms, but we find that firms in tradables sectors and firms in the lowest productivity quintile have a significantly higher probability of exit after the treatment. The latter result suggests that the additional strain on low-productivity firms caused by the tolls has induced a kind of market-clearing or creative destruction.

The majority of effects for all these outcomes are medium- to long-term, i.e. still persistent nine years after the introduction of tolls. All main conclusions proved stable to a plethora of robustness checks.

Our findings do not only contribute to a better understanding of the behavior of firms confronted with an exogeneous shock, but provide policymakers with insights into the firm-level reactions to policy-induced distortions that can help them design better policies. We hope that this study will stimulate further research on the complex private sector effects of government intervention into the transportation sector. Our findings suggest that lower productivity firms suffer more from the transportation cost shock than higher productivity firms. A related and potentially fruitful area for future research is further disentangling the impact of a transportation cost shock on the financial conditions of

[37] One interesting exception occurs for profits: when we use the logarithmic transformation, the effect becomes negative (−6%). However, sample size also drops considerably. In addition, the results for total expenses and full-time workers are noisier when these variables are considered in levels.

firms, depending on their pre-treatment level of debt and their relations with the banking system.

CRediT authorship contribution statement

Catarina Branco: Software, Formal analysis, Investigation, Data curation, Writing – review & editing. **Dirk C. Dohse:** Conceptualization, Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **João Pereira dos Santos:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **José Tavares:** Conceptualization, Investigation, Supervision, Validation, Visualization, Writing – review & editing.

Appendix

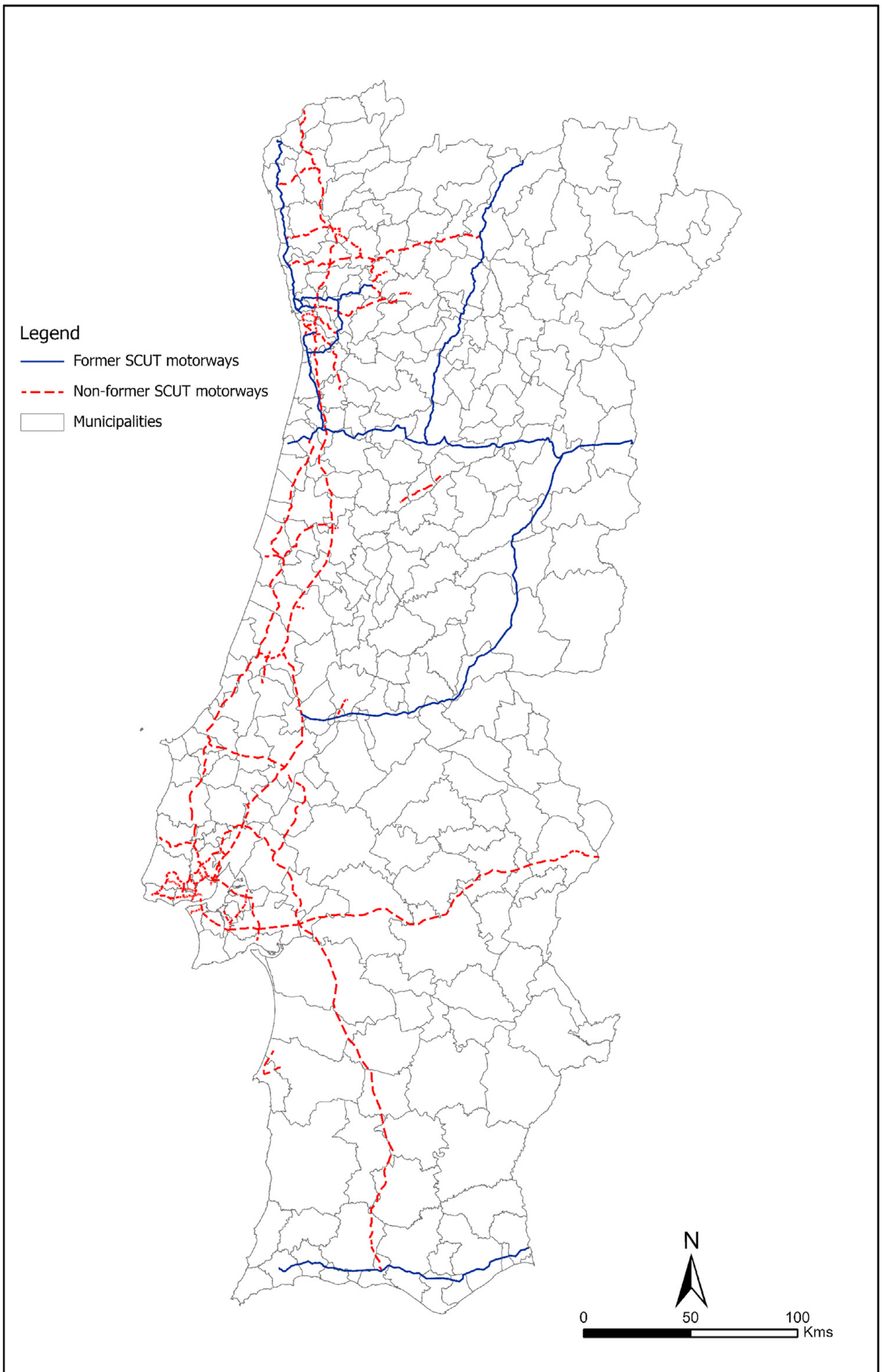

Fig. A.1. SCUT and non-SCUT highways.
Notes: Non-former SCUT motorways are all the alternative (non-SCUT) highways.

Table A.1
Variable description – main and secondary variables.

Variable	Notes
Firm Performance	
Total revenues	It includes turnover, operating subsidies, and Income from financial assets (in euros)
Turnover	sales of goods and services (in euros)
Sales of services	sales of services provided by the firm (in euros)
Profits	Earnings before taxes, including interest payments, depreciations and amortization (in euros)
Net income	Total revenues minus total expenses (in euros)
Labor productivity	Turnover divided by workers (in euros)
Firm Behavior	
Total expenses	It includes materials, services, employee, interest payments, and taxes (in euros)
Materials	Costs of goods sold and material consumed (in euros)
Services (inputs)	Supplies and external services (in euros)
Employee	It includes social security expenses and insurance schemes for accidents and diseases (in euros)
FT workers	Number of full-time workers
PT workers	Number of part-time workers
Av wages	Salaries divided by workers (in euros)
Domestic turnover	(in euros)
Prob exporting	1 if the firm exports; 0 otherwise
Exports	(in euros)
Exports EU	It included sales to the UK (in euros)
Exports non-EU	(in euros)
Inventory	Variation in production (in euros)
Prob exit	1 if the firm exits; 0 otherwise

Table A.2
Descriptive statistics for the full sample period (2006–2019) – secondary variables.

	Comparison			Treated		
Secondary variables	Mean	Std. Dev.	N x T	Mean	Std. Dev.	N x T
Firm Performance						
Total revenues	1,167,792	28,043,129	3,003,375	977,342	18,103,859	752,058
Sales of services	311,439	8,293,314	3,003,375	231,790	3,082,225	752,058
Net income	36,641	4,683,449	3,003,375	33,915	2,126,068	752,058
Firm Behavior						
Costs of Materials	587,589	21,091,152	3,003,375	509,186	12,953,727	752,058
Services (inputs)	256,003	5,775,874	3,003,375	199,523	3,081,258	752,058
Employee-related expenses	150,729	2,085,569	3,003,375	129,020	1,583,183	752,058
Part-time paid employment	0.8	28.9	1,814,321	0.9	43.9	452,579
Prob of exporting	0.141	0.348	3,003,375	0.156	0.363	752,058
Exports EU	144,365	6,557,899	3,003,375	130,265	3,185,756	752,058
Exports non-EU	62,351	4,600,077	3,003,375	55,693	2,494,032	752,058

Table A.3
Descriptive Statistics for the full sample period (2006–2019) – Municipal-level control variables.

	Comparison			Treated		
Variable	Mean	Std. Dev.	N x T	Mean	Std. Dev.	N x T
Population density	17.027	21.48	3,003,375	16.622	18.61	752,058
Withdrawals on ATMs per capita	2505.127	953.384	3,003,375	2474.708	885.089	752,058
Mean value of traded real estates	121671.759	93999.780	3,003,375	98109.820	48515.230	752,058
Municipal expenditures per capita	805.515	384.931	3,003,375	706.473	312.504	752,058

Table A.4
Balance table using the pre-treatment period (2006–2010).

	Treatment	Control	Difference	(Std error)
Firm performance				
Turnover	810,595	946,709	−136,114	(163,794)
EBT	34,442	49,066	−14,624	(22,030)
Labor Productivity	93,062	92,761	301.2	(9733)
Firm behavior				
Total expenses	851,471	999,020	−147,549	(178,966)
Average wages	9676	9970	−293.9	(441.1)
Full-time employees	7.612	8.077	−0.465	(0.590)
Domestic turnover	667,551	802,936	−135,385	(154,042)
Exports	143,044	143,774	−729.5	(25,591)
Inventory	217,396	228,718	−11,322	(17,288)
Probability of exit	0.031	0.032	0.001	(0.001)

Notes: Standard errors in parenthesis are clustered at the municipal level. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Further heterogeneity results

Table AR.9

Table AH.1
Heterogeneity: Performance indicators - Triple DiD.

	Turnover		Profits		Labor productivity	
	(1)	(2)	(3)	(4)	(5)	(6)
$Treated \times Post \times LP_{Q1}$	−0.150*		0.116		−0.032	
	(0.081)		(0.115)		(0.033)	
$Treated \times Post \times LP_{Q5}$		−0.034		−0.118		−0.001
		(0.032)		(0.088)		(0.015)
Firm FE	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y
$N \times T$	2,327,935	2,457,523	2,327,905	2,457,450	2,100,708	2,267,730
R^2	0.569	0.531	0.396	0.385	0.567	0.475

Notes: Standard errors in parenthesis are clustered at the municipal level. All variables are measured using the inverse hyperbolic sine transformation. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AH.2
Heterogeneity: Behavior indicators - Triple DiD.

	Expenses		Av Wages		Full-time workers		Inventory		Prob exit	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$Treated \times Post \times LP_{Q1}$	−0.112*		−0.015*		−0.025*		−0.051		0.005*	
	(0.059)		(0.008)		(0.015)		(0.047)		(0.003)	
$Treated \times Post \times LP_{Q5}$		−0.028		−0.001		0.008		−0.003		−0.000
		(0.027)		(0.006)		(0.009)		(0.037)		(0.001)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
$N \times T$	2,327,935	2,457,523	2,100,708	2,267,730	2,227,614	2,372,183	2,327,935	2,457,523	2,327,935	2,457,523
R^2	0.576	0.616	0.570	0.643	0.823	0.844	0.801	0.814	0.274	0.245

Notes: Standard errors in parenthesis are clustered at the municipal level. All variables, with the exception of probability of exit, are measured using the inverse hyperbolic sine transformation. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

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Further robustness tests

Table AR.1
Robustness: Profits – Part I.

	Profits (ihs)							
	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treated × *Post*	−0.041 (0.078)			−0.028 (0.083)	−0.055 (0.073)	−0.057 (0.073)	−0.057 (0.057)	−0.040 (0.078)
Quartile × *Post*		−0.055 (0.067)						
Sixtile × *Post*			−0.046 (0.082)					
Ring × *Post*				0.024 (0.070)				
NoSCUT × *Post*								−0.020 (0.041)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	N	N	Y	Y
NUTS 3– Year FE	N	N	N	N	Y	Y	N	N
Controls	N	N	N	N	N	Y	N	N
Sector– Year FE	N	N	N	N	N	N	Y	N
$N \times T$	3,753,757	3,753,757	3,753,757	3,753,757	3,753,757	3,753,757	3,753,372	3,753,757
R^2	0.415	0.415	0.415	0.415	0.416	0.416	0.426	0.415

Notes: Profits are proxied using earnings before taxes. Standard errors in parenthesis are clustered at the municipal level. Nuts 2 (3) comprises 5 (25) groups of regions. The vector of annual municipal-level controls comprises Population density, Withdrawals on ATMs (automated teller machines) per capita, Mean value of traded real estates, and Municipal expenditures per capita. Sector comprises 816 groups of 5-digit sectors of activity. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AR.2
Robustness: Profits – Part II.

	Profits (ihs)						ln(Profits+1)	Profits
	Only NW	Single	No DC	No Lisbon	Winsor	Balanced		
Treated × *Post*	0.013 (0.112)	−0.035 (0.079)	−0.145* (0.087)	−0.033 (0.080)	−0.034 (0.076)	−0.068 (0.074)	−0.060** (0.029)	542.476 (3671.951)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y	Y	Y
$N \times T$	1,289,279	3,631,487	2,621,965	2,510,598	3,753,863	2,157,811	2,349,055	3,753,863
R^2	0.426	0.416	0.415	0.422	0.411	0.398	0.747	0.334

Notes: Profits are proxied using earnings before taxes. Standard errors in parenthesis are clustered at the municipal level. No DC removes all firms in district capitals while only NW considers only firms in the four northwestern districts of Viana do Castelo, Braga, Porto, and Aveiro. Winsorization of the outcome variable at the 90th percentile in column (11). Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AR.3
Robustness: Labor Productivity – Part I.

	Labor productivity (ihs)							
	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treated × *Post*	−0.043*** (0.013)			−0.029* (0.016)	−0.042*** (0.012)	−0.043*** (0.012)	−0.042*** (0.012)	−0.043*** (0.013)
Quartile × *Post*		−0.033** (0.013)						
Sixtile × *Post*			−0.041*** (0.014)					
Ring × *Post*				0.026* (0.014)				
NoSCUT × *Post*								−0.009 (0.013)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	N	N	Y	Y
NUTS 3– Year FE	N	N	N	N	Y	Y	N	N
Controls	N	N	N	N	N	Y	N	N
Sector– Year FE	N	N	N	N	N	N	Y	N
$N \times T$	2,812,764	2,812,764	2,812,764	2,812,764	2,812,764	2,812,764	2,812,280	2,812,764
R^2	0.597	0.597	0.597	0.597	0.597	0.597	0.602	0.597

Notes: Standard errors in parenthesis are clustered at the municipal level. Nuts 2 (3) comprises 5 (25) groups of regions. The vector of annual municipal-level controls comprises Population density, Withdrawals on ATMs (automated teller machines) per capita, Mean value of traded real estates, and Municipal expenditures per capita. Sector comprises 816 groups of 5-digit sectors of activity. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AR.4
Robustness: Labor Productivity – Part II.

	Labor productivity (ihs)						ln(LP+1)	LP
	Only NW	Single	No DC	No Lisbon	Winsor	Balanced		
$Treated \times Post$	−0.063***	−0.045***	−0.055***	−0.041***	−0.029***	−0.042***	−0.043***	−6432.433**
	(0.015)	(0.013)	(0.013)	(0.013)	(0.006)	(0.012)	(0.012)	(2932.308)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y	Y	Y
$N \times T$	1,000,489	2,695,960	2,007,212	1,925,241	2,812,764	1,736,043	2,812,764	2,812,764
R^2	0.605	0.596	0.593	0.597	0.766	0.625	0.602	0.618

Notes: Standard errors in parenthesis are clustered at the municipal level. No DC removes all firms in district capitals while only NW considers only firms in the four northwestern districts of Viana do Castelo, Braga, Porto, and Aveiro. Winsorization of the outcome variable at the 90th percentile in column (11). Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AR.5
Robustness: Total expenses – Part I.

	Expenses (ihs)							
	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Treated \times Post$	−0.079**			−0.078*	−0.081**	−0.081**	−0.084***	−0.077**
	(0.031)			(0.046)	(0.032)	(0.034)	(0.031)	(0.031)
$Quartile \times Post$		−0.071*						
		(0.037)						
$Sixtile \times Post$			−0.064*					
			(0.034)					
$Ring \times Post$				0.003				
				(0.043)				
$NoSCUT \times Post$								−0.039
								(0.051)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	N	N	Y	Y
NUTS 3– Year FE	N	N	N	N	Y	Y	N	N
Controls	N	N	N	N	N	Y	N	N
Sector– Year FE	N	N	N	N	N	N	Y	N
$N \times T$	3,753,863	3,753,863	3,753,863	3,753,863	3,753,863	3,753,863	3,753,479	3,753,863
R^2	0.699	0.699	0.699	0.699	0.699	0.699	0.706	0.699

Notes: Standard errors in parenthesis are clustered at the municipal level. Nuts 2 (3) comprises 5 (25) groups of regions. The vector of annual municipal-level controls comprises Population density, Withdrawals on ATMs (automated teller machines) per capita, Mean value of traded real estates, and Municipal expenditures per capita. Sector comprises 816 groups of 5-digit sectors of activity. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AR.6
Robustness: Total Expenses – Part II.

	Expenses (ihs)						ln(Expenses+1)	Expenses
	Only NW	Single	No DC	No Lisbon	Winsor	Balanced		
$Treated \times Post$	−0.090**	−0.083***	−0.123***	−0.059*	−0.042***	−0.066***	−0.078***	−51556.924
	(0.038)	(0.032)	(0.037)	(0.030)	(0.013)	(0.023)	(0.030)	(32941.463)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y	Y	Y
$N \times T$	1,289,294	3,631,567	2,622,017	2,510,628	3,753,863	2,157,858	3,753,863	3,753,863
R^2	0.694	0.704	0.703	0.702	0.781	0.737	0.706	0.929

Notes: Standard errors in parenthesis are clustered at the municipal level. No DC removes all firms in district capitals while only NW considers only firms in the four northwestern districts of Viana do Castelo, Braga, Porto, and Aveiro. Winsorization of the outcome variable at the 90th percentile in column (11). Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AR.7
Robustness: Full-time workers – Part I.

	Full-time workers (ihs)							
	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Treated \times Post$	−0.016**			−0.019**	−0.016**	−0.016**	−0.026***	−0.016**
	(0.006)			(0.008)	(0.006)	(0.006)	(0.006)	(0.006)
$Quartile \times Post$		−0.016**						
		(0.006)						
$Sixtile \times Post$			−0.014**					
			(0.007)					
$Ring \times Post$				−0.006				
				(0.007)				
$NoSCUT \times Post$								−0.006
								(0.007)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	N	N	Y	Y
NUTS 3– Year FE	N	N	N	N	Y	Y	N	N
Controls	N	N	N	N	N	Y	N	N
Sector– Year FE	N	N	N	N	N	N	Y	N
$N \times T$	3,337,876	3,337,876	3,337,876	3,337,876	3,337,876	3,337,876	3,337,423	3,337,876
R^2	0.853	0.853	0.853	0.853	0.853	0.853	0.859	0.853

Notes: Standard errors in parenthesis are clustered at the municipal level. Nuts 2 (3) comprises 5 (25) groups of regions. The vector of annual municipal-level controls comprises Population density, Withdrawals on ATMs (automated teller machines) per capita, Mean value of traded real estates, and Municipal expenditures per capita. Sector comprises 816 groups of 5-digit sectors of activity. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AR.8
Robustness: Full-time workers – Part II.

	Full-time workers (ihs)						ln(FTW+0.1)	FTW
	Only NW	Single	No DC	No Lisbon	Winsor	Balanced		
$Treated \times Post$	−0.014*	−0.016**	−0.026***	−0.014**	−0.012**	−0.018***	−0.013***	−0.112
	(0.008)	(0.007)	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)	(0.141)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y	Y	Y
$N \times T$	1,162,225	3,219,053	2,354,689	2,251,399	3,337,876	1,966,889	3,337,876	3,337,876
R^2	0.862	0.845	0.854	0.853	0.823	0.873	0.863	0.913

Notes: Standard errors in parenthesis are clustered at the municipal level. No DC removes all firms in district capitals while only NW considers only firms in the four northwestern districts of Viana do Castelo, Braga, Porto, and Aveiro. Winsorization of the outcome variable at the 90th percentile in column (11). Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AR.9
Robustness: Average Wages – Part I.

	Average Wages (ihs)							
	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Treated \times Post$	−0.020***			−0.021***	−0.014***	−0.014***	−0.018***	−0.020***
	(0.005)			(0.006)	(0.004)	(0.004)	(0.005)	(0.005)
$Quartile \times Post$		−0.020***						
		(0.006)						
$Sixtile \times Post$			−0.019***					
			(0.005)					
$Ring \times Post$				−0.002				
				(0.005)				
$NoSCUT \times Post$								−0.011***
								(0.004)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	N	N	Y	Y
NUTS 3– Year FE	N	N	N	N	Y	Y	N	N
Controls	N	N	N	N	N	Y	N	N
Sector– Year FE	N	N	N	N	N	N	Y	N
$N \times T$	2,812,764	2,812,764	2,812,764	2,812,764	2,812,764	2,812,764	2,812,280	2,812,764
R^2	0.631	0.631	0.631	0.631	0.631	0.631	0.635	0.631

Notes: Standard errors in parenthesis are clustered at the municipal level. Nuts 2 (3) comprises 5 (25) groups of regions. The vector of annual municipal-level controls comprises Population density, Withdrawals on ATMs (automated teller machines) per capita, Mean value of traded real estates, and Municipal expenditures per capita. Sector comprises 816 groups of 5-digit sectors of activity. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AR.10
Robustness: Average Wages – Part II.

	Average Wages (ihs)						ln(AW+1)	AW
	Only NW	Single	No DC	No Lisbon	Winsor	Balanced		
Treated × *Post*	−0.030***	−0.020***	−0.024***	−0.019***	−0.015***	−0.022***	−0.020***	−139.994***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(49.313)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y	Y	Y
$N \times T$	1,000,489	2,695,960	2,007,212	1,925,241	2,812,764	1,736,043	2,812,764	2,812,764
R^2	0.617	0.625	0.619	0.605	0.730	0.673	0.632	0.661

Notes: Standard errors in parenthesis are clustered at the municipal level. No DC removes all firms in district capitals while only NW considers only firms in the four northwestern districts of Viana do Castelo, Braga, Porto, and Aveiro. Winsorization of the outcome variable at the 90th percentile in column (11). Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AR.11
Robustness: Inventory – Part I.

	Inventory (ihs)							
	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treated × *Post*	0.006			0.018	−0.011	−0.011	−0.032	0.009
	(0.032)			(0.040)	(0.032)	(0.033)	(0.035)	(0.031)
Quartile × *Post*		0.008						
		(0.031)						
Sixtile × *Post*			0.009					
			(0.036)					
Ring × *Post*				0.021				
				(0.033)				
NoSCUT × *Post*								−0.044
								(0.041)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	N	N	Y	Y
NUTS 3– Year FE	N	N	N	N	Y	Y	N	N
Controls	N	N	N	N	N	Y	N	N
Sector– Year FE	N	N	N	N	N	N	Y	N
$N \times T$	3,753,863	3,753,863	3,753,863	3,753,863	3,753,863	3753863	3,753,479	3,753,863
R^2	0.815	0.815	0.815	0.815	0.815	0.815	0.820	0.815

Notes: Standard errors in parenthesis are clustered at the municipal level. Nuts 2 (3) comprises 5 (25) groups of regions. The vector of annual municipal-level controls comprises Population density, Withdrawals on ATMs (automated teller machines) per capita, Mean value of traded real estates, and Municipal expenditures per capita. Sector comprises 816 groups of 5-digit sectors of activity. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AR.12
Robustness: Inventory – Part II.

	Inventory (ihs)						ln(Inventory+1)	Inventory
	Only NW	Single	No DC	No Lisbon	Winsor	Balanced		
Treated × *Post*	−0.005	0.011	−0.051	0.020	0.006	0.035	0.005	−11485.269**
	(0.038)	(0.032)	(0.035)	(0.031)	(0.032)	(0.027)	(0.030)	(4705.109)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y	Y	Y	Y
$N \times T$	1,289,294	3,631,567	2,622,017	2,510,628	3,753,863	2,157,858	3,753,863	3,753,863
R^2	0.815	0.814	0.813	0.812	0.815	0.846	0.817	0.834

Notes: Standard errors in parenthesis are clustered at the municipal level. No DC removes all firms in district capitals while only NW considers only firms in the four northwestern districts of Viana do Castelo, Braga, Porto, and Aveiro. Winsorization of the outcome variable at the 90th percentile in column (11). Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AR.13
Robustness: Probability of exit – Part I.

	Prob exit							
	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Treated \times Post$	0.006** (0.002)			0.006* (0.003)	0.005 (0.003)	0.005 (0.003)	0.005* (0.003)	0.006** (0.002)
$Quartile \times Post$		0.005* (0.003)						
$Sixtile \times Post$			0.006* (0.003)					
$Ring \times Post$				−0.000 (0.003)				
$NoSCUT \times Post$								0.002 (0.005)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	N	N	Y	Y
NUTS 3– Year FE	N	N	N	N	Y	Y	N	N
Controls	N	N	N	N	N	Y	N	N
Sector– Year FE	N	N	N	N	N	N	Y	N
$N \times T$	4,871,327	4,871,327	4,871,327	4,871,327	4,871,327	4,871,327	4,870,975	4,871,327
R^2	0.390	0.390	0.390	0.390	0.390	0.390	0.394	0.390

Notes: Standard errors in parenthesis are clustered at the municipal level. Nuts 2 (3) comprises 5 (25) groups of regions. The vector of annual municipal-level controls comprises Population density, Withdrawals on ATMs (automated teller machines) per capita, Mean value of traded real estates, and Municipal expenditures per capita. Sector comprises 816 groups of 5-digit sectors of activity. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Table AR.14
Robustness: Probability of exit – Part II.

	Prob exit				
	Only NW	Single	No DC	No Lisbon	Balanced
$Treated \times Post$	0.006* (0.003)	0.006** (0.002)	0.007** (0.003)	0.004** (0.002)	0.002* (0.001)
Firm FE	Y	Y	Y	Y	Y
NUTS 2– Year FE	Y	Y	Y	Y	Y
$N \times T$	1,686,125	4,730,904	3,391,952	3,237,922	2,157,858
R^2	0.394	0.393	0.394	0.392	0.463

Notes: Standard errors in parenthesis are clustered at the municipal level. No DC removes all firms in district capitals while only NW considers only firms in the four northwestern districts of Viana do Castelo, Braga, Porto, and Aveiro. Asterisks indicate significance levels of 10% (*), 5% (**), and 1%(***), respectively.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.jue.2023.103569.

References

Abeberese, A.B., Chen, M., 2022. Intranational trade costs, product scope and productivity: evidence from India's golden quadrilateral project. J. Dev. Econ. 156, 102791.
Alexandre, F., Bação, P., Cerejeira, J.a., Costa, H., Portela, M., 2022. Minimum wage and financially distressed firms: another one bites the dust. Labour Econ. 74, 102088.
Amador, J.a., Soares, A.C., 2012. A concorrência na Economia Portuguesa: Uma Visão Sobre os Setores Transacionável e não Transacionável. Technical Report. Boletim Económico da Primavera do Banco de Portugal.
Angrist, J., Pischke, J.-S., 2008. Mostly Harmless Econometrics: An Empiricist's Companion. Princeton University Press.
Asturias, J., García-Santana, M., Ramos, R., 2019. Competition and the welfare gains from transportation infrastructure: evidence from the golden quadrilateral of India. J. Eur. Econ. Assoc. 17 (6), 1881–1940.
Athey, S., Imbens, G.W., 2022. Design-based analysis in difference-in-differences settings with staggered adoption. J. Econom. 226 (1), 62–79.
Audretsch, D.B., Dohse, D.C., dos Santos, J.P., 2020. The effects of highway tolls on private business activity - results from a natural experiment. J. Econ. Geogr. 20 (6), 1331–1357. doi:10.1093/jeg/lbaa003.
Banerjee, A., Duflo, E., Qian, N., 2012. On the Road: Access to Transportation Infrastructure and Economic Growth in China. Working Paper. National Bureau of Economic Research doi:10.3386/w17897.
Barzin, S., D'Costa, S., Graham, D.J., 2018. A pseudo–panel approach to estimating dynamic effects of road infrastructure on firm performance in a developing country context. Reg. Sci. Urban Econ. 70, 20–34.
Bastos, P., Silva, J., Verhoogen, E., 2018. Export destinations and input prices. Am. Econ. Rev. 108 (2), 353–392.
Baum-Snow, N., 2007. Did highways cause suburbanization? Q. J. Econ. 122 (2), 775–805. doi:10.1162/qjec.122.2.775.
Baum-Snow, N., 2020. Urban transport expansions and changes in the spatial structure of US cities: implications for productivity and welfare. Rev. Econ. Stat. 102 (5), 929–945.
Baum-Snow, N., Brandt, L., Henderson, J.V., Turner, M.A., Zhang, Q., 2017. Roads, railroads, and decentralization of Chinese cities. Rev. Econ. Stat. 99 (3), 435–448. doi:10.1162/REST_a_00660.
Baum-Snow, N., Henderson, J.V., Turner, M.A., Zhang, Q., Brandt, L., 2020. Does investment in national highways help or hurt hinterland city growth? J. Urban Econ. 115, 103124.
Behrens, K., Brown, W.M., Bougna, T., 2018. The world is not yet flat: transport costs matter!. Rev. Econ. Stat. 100 (4), 712–724.
Bellemare, M.F., Wichman, C.J., 2020. Elasticities and the inverse hyperbolic sine transformation. Oxf. Bull. Econ. Stat. 82 (1), 50–61.
Bertrand, M., Duflo, E., Mullainathan, S., 2004. How much should we trust differences-in-differences estimates? Q. J. Econ. 119 (1), 249–275. doi:10.1162/003355304772839588.
Borusyak, K., Jaravel, X., Spiess, J., 2021. Revisiting event study designs: robust and efficient estimation. Unpublished working paper, version May 19, 2021.
Brooks, W., Donovan, K., 2020. Eliminating uncertainty in market access: the impact of new bridges in rural Nicaragua. Econometrica 88 (5), 1965–1997.
Butts, K., 2021. Difference-in-differences estimation with spatial spillovers. Technical Report. arXiv preprint arXiv:2105.03737.
Cabral, L., 2007. Small firms in portugal: a selective survey of stylized facts, economic analysis, and policy implications. Portuguese Econ. J. 6 (1), 65–88.
Callaway, B., Sant'Anna, P., 2021. Difference-in-differences with multiple time periods. J. Econom. 225 (2), 200–230.
Carneiro, A., Portugal, P., Varejao, J., 2014. Catastrophic job destruction during the Portuguese economic crisis. J. Macroecon. 39, 444–457. doi:10.1016/j.jmacro.2013.09.018.

Carvalho, B.P., Peralta, S., Pereira dos Santos, J.a., 2022. Regional and sectorial impacts of the COVID-19 crisis: evidence from electronic payments. J. Reg. Sci. 62 (3), 757–798.
Chen, J., Roth, J., 2022. Log-like? Identified ATEs defined with zero-valued outcomes are (arbitrarily) scale-dependent.
Chauvet, L., Ferry, M., 2021. Taxation, infrastructure, and firm performance in developing countries. Public Choice 187, 455–480.
Chen, S., He, X., 2015. Road to success? The effects of road toll on economic growth in China. Appl. Econ. Lett. 22 (2), 158–162.
Coşar, A.K., Demir, B., Ghose, D., Young, N., 2022. Road capacity, domestic trade and regional outcomes. J. Econ. Geogr. 22 (5), 901–929.
Datta, S., 2012. The impact of improved highways on Indian firms. J. Dev. Econ. 99 (1), 46–57. doi:10.1016/j.jdeveco.2011.08.005.
De Chaisemartin, C., d'Haultfoeuille, X., 2020. Two-way fixed effects estimators with heterogeneous treatment effects. Am. Econ. Rev. 110 (9), 2964–2996.
Dias, D.A., Marques, C.R., Martins, F., 2013. Wage rigidity and employment adjustment at the firm level: evidence from survey data. Labour Econ. 23, 40–49.
Díez-Gutiérrez, M., Andersen, S.N., Nilsen, O.L., Tørset, T., 2019. Generated and induced traffic demand: empirical evidence from a fixed link toll removal in Norway. Case Stud. Transp. Policy 7 (1), 57–63.
Donaldson, D., 2018. Railroads of the raj: estimating the impact of transportation infrastructure. Am. Econ. Rev. 108 (4–5), 899–934.
Duranton, G., 2015. Roads and trade in Colombia. Econ. Transp. 4 (1–2), 16–36.
Duranton, G., Morrow, P.M., Turner, M.A., 2014. Roads and trade: evidence from the US. Rev. Econ. Stud. 81 (2), 681–724. doi:10.1093/restud/rdt039.
Faber, B., 2014. Trade integration, market size, and industrialization: evidence from China's national trunk highway system. Rev. Econ. Stud. 81 (3), 1046–1070. doi:10.1093/restud/rdu010.
Fan, J., Lu, Y., Luo, W., 2019. Valuing domestic transport infrastructure: a view from the route choice of exporters. Rev. Econ. Stat. 1–46.
Fernandes, C., Ferreira, M., Moura, F., 2016. PPPs - true financial costs and hidden returns. Transp. Rev. 36 (2), 207–227.
Fernandes, C., Viegas, J.M., 1999. Private financing of road infrastructure: the Portuguese experience. Transp. Res. Rec. 1659 (1), 23–30.
Fernandes, C., Viegas, J.M., et al., 2005. Portuguese experience in motorway concessions with real and shadow tolls. Res. Transp. Econ. 15 (1), 157–174.
Figueiredo, O., Guimaraes, P., Woodward, D., 2002. Home-field advantage: location decisions of Portuguese entrepreneurs. J. Urban Econ. 52 (2), 341–361.
Fiorini, M., Sanfilippo, M., Sundaram, A., 2021. Trade liberalization, roads and firm productivity. J. Dev. Econ. 102712.
Gabriel, J.M., dos Santos, J.P., Tavares, J., 2022. European Funds and firm Performance: Evidence from a Natural Experiment. Technical Report. Ruhr Economic Papers.
Garcia-López, M.-A., Holl, A., Viladecans-Marsal, E., 2015. Suburbanization and highways in Spain when the Romans and the Bourbons still shape its cities. J. Urban Econ. 85, 52–67.
Ghani, E., Goswami, A.G., Kerr, W.R., 2016. Highway to success: the impact of the golden quadrilateral project for the location and performance of Indian manufacturing. Econ. J. 126 (591), 317–357. doi:10.1111/ecoj.12207.
Gibbons, S., Lyytikäinen, T., Overman, H.G., Sanchis-Guarner, R., 2019. New road infrastructure: the effects on firms. J. Urban Econ. 110, 35–50.
Goodman-Bacon, A., 2021. Difference-in-differences with variation in treatment timing. J. Econom. 225 (2), 254–277.
Gouveia, A.F., Canas, F., 2016. Reallocation of Resources Between Tradable and Non-Tradable Sectors in Portugal: Developing a New Identification Strategy for the Tradable Sector. Technical Report. Gabinete de Estratégia e Estudos, Ministério da Economia.
Graham, D., 2007. Agglomeration, productivity and transport investment. J. Transp. Econ. Policy 41 (3), 317–343.
Graham, D.J., 2007. Variable returns to agglomeration and the effect of road traffic congestion. J. Urban Econ. 62 (1), 103–120. doi:10.1016/j.jue.2006.10.001.
Haughwout, A.F., 2002. Public infrastructure investments, productivity and welfare in fixed geographic areas. J. Public Econ. 83 (3), 405–428.
He, G., Xie, Y., Zhang, B., 2020. Expressways, GDP, and the environment: the case of China. J. Dev. Econ. 145, 102485.
Herzog, I., 2021. National transportation networks, market access, and regional economic growth. J. Urban Econ. 122, 103316.
Holl, A., 2004. Transport infrastructure, agglomeration economies, and firm birth: empirical evidence from Portugal. J. Reg. Sci. 44 (4), 693–712.
Holl, A., 2006. A review of the firm-level role of transport infrastructure with implications for transport project evaluation. J. Plan. Lit. 21 (1), 3–14.
Holl, A., 2012. Market potential and firm-level productivity in Spain. J. Econ. Geogr. 12 (6), 1191–1215. doi:10.1093/jeg/lbr030.
Holl, A., 2016. Highways and productivity in manufacturing firms. J. Urban Econ. 93, 131–151.
Holl, A., Mariotti, I., 2018. Highways and firm performance in the logistics industry. J. Transp. Geogr. 72, 139–150.
Jaworski, T., Kitchens, C.T., 2019. National policy for regional development: historical evidence from appalachian highways. Rev. Econ. Stat. 101 (5), 777–790.
Instituto Nacional de Estatística (INE), 2008. Estatísticas de transporte e comunicação 2008.
Instituto Nacional de Estatística (INE), 2015. Estatísticas de transporte e comunicação 2014.
Jedwab, R., Storeygard, A., 2022. The average and heterogeneous effects of transportation investments: evidence from Sub-Saharan Africa 1960–2010. J. Eur. Econ. Assoc. 20 (1), 1–38.
Kajitani, Y., Tatano, H., 2014. Estimation of production capacity loss rate after the great east Japan earthquake and tsunami in 2011. Econ. Syst. Res. 26 (1), 13–38.
Lall, S.V., Shalizi, Z., Deichmann, U., 2004. Agglomeration economies and productivity in Indian industry. J. Dev. Econ. 73 (2), 643–673. doi:10.1016/j.jdeveco.2003.04.006.
Li, H., Li, Z., 2013. Road investments and inventory reduction: firm level evidence from China. J. Urban Econ. 76, 43–52.
Martin-Barroso, D., Núñez Serrano, J., Velázquez, F., 2015. The effect of accessibility on productivity in Spanish manufacturing firms. J. Reg. Sci. 55 (5), 708–735.
Martincus, C.V., Blyde, J., 2013. Shaky roads and trembling exports: assessing the trade effects of domestic infrastructure using a natural experiment. J. Int. Econ. 90 (1), 148–161.
Martincus, C.V., Carballo, J., Cusolito, A., 2017. Roads, exports and employment: evidence from a developing country. J. Dev. Econ. 125, 21–39.
Martincus, C.V., Carballo, J., Garcia, P., 2012. Public programmes to promote firms' exports in developing countries: are there heterogeneous effects by size categories? Appl. Econ. 44 (4), 471–491.
Martincus, C.V., Carballo, J., Garcia, P., Graziano, A., 2014. How do transport costs affect firms' exports? Evidence from a vanishing bridge. Econ. Lett. 123 (2), 149–153.
Meland, S., Tretvik, T., Welde, M., 2010. The effects of removing the Trondheim toll cordon. Transp. Policy 17 (6), 475–485.
Melo, P.C., Rego, C.a., Anciães, P.R., Guiomar, N., Muñoz Rojas, J., 2022. Does road accessibility to cities support rural population growth? Evidence for Portugal between 1991 and 2011. J. Reg. Sci. 62, 443–470.
Michaels, G., Rauch, F., Redding, S.J., 2012. Urbanization and structural transformation. Q. J. Econ. 127 (2), 535–586. doi:10.1093/qje/qjs003.
Mullahy, J., Norton, E.C., 2022. Why Transform Y? A Critical Assessment of Dependent–Variable Transformations in Regression Models for Skewed and Sometimes-Zero Outcomes. Technical Report. National Bureau of Economic Research.
Pereira, A.M., Andraz, J.M., 2005. Public investment in transportation infrastructure and economic performance in Portugal. Rev. Dev. Econ. 9 (2), 177–196.
Pereira, A.M., Pereira, R.M., dos Santos, J.P., 2021. For whom the bell tolls: road safety effects of tolls on uncongested SCUT highways in Portugal. J. Infrastruct., Policy Dev. 4 (2), 287–305.
Redding, S.J., Turner, M.A., 2015. Chapter 20—Transportation costs and the spatial organization of economic activity. In: Duranton, G., Henderson, J.V., Strange, W.C. (Eds.), Handbook of Regional and Urban Economics. In: Handbook of Regional and Urban Economics, vol. 5. Elsevier, pp. 1339–1398. doi:10.1016/B978-0-444-59531-7.00020-X.
Rocha, B.T., Afonso, N., Melo, P.C., de Abreu e Silva, J., 2022. What drives the allocation of motorways? Evidence from Portugal's fast-expanding network. J. Transp. Geogr. 102, 103384.
Rocha, B. T., Melo, P. C., Afonso, N., de Abreu e Silva, J., 2021. Motorways, urban growth, and suburbanisation: evidence from three decades of motorway construction in Portugal.
Roth, J., 2022. Pretest with caution: event-study estimates after testing for parallel trends. Am. Econ. Rev. 4 (3), 305–322.
Roth, J., Sant'Anna, P. H. C., Bilinski, A., Poe, J., 2022. What's trending in difference-in-differences? A synthesis of the recent econometrics literature. Technical Report. arXiv preprint arXiv:2201.01194.
Sant'Anna, P.H.C., Zhao, J., 2020. Doubly robust difference-in-differences estimators. J. Econom. 219 (1), 101–122.
dos Santos, J.a.P., Tavares, J., Vicente, P.C., 2021. Can ATMs get out the vote? Evidence from a nationwide field experiment. Eur. Econ. Rev. 134, 103691.
Santos, M.G., Santos, B.F., 2012. Shadow-tolls in portugal: how we got here and what were the impacts of introducing real tolls. In: European Transport Conference, vol. 2012.
Sarmento, J.M., 2010. Do public-private partnerships create value for money for the public sector? The Portuguese experience. OECD J. Budgeting 10 (1), 1–27.
Shirley, C., Winston, C., 2004. Firm inventory behavior and the returns from highway infrastructure investments. J. Urban Econ. 55 (2), 398–415.
Storeygard, A., 2016. Farther on down the road: transport costs, trade and urban growth in Sub-Saharan Africa. Rev. Econ. Stud. 83 (3), 1263–1295.
Wise, P., 2013. High toll charges leave Portugal's drivers on road to nowhere. Financ. Times. https://www.ft.com/content/59949c24-0a3a-11e3-9cec-00144feabdc0.