1. Introduction

A series of recent papers have assessed the effects of domestic transport infrastructure on a number of economic outcomes across both developed and developing countries typically in cross-region settings (see Redding and Turner, 2014 for an excellent survey of this literature). Overall, this body of research conveys a consistent message: infrastructure seems to have been an important driving force for the variables considered in these studies. When it comes to how transport networks affect trade, evidence from this literature based on data at the level of geographical units is relatively more scarce (e.g., Jacobsy, 2006; Jacobsy and Minter, 2009 and Gertler et al., 2014).1

This paper contributes to this growing literature by showing the impact of road infrastructure on international trade using micro data from a developing country as opposed to the more aggregated data utilized previously.2

More specifically, we address one main question: What are the effects of domestic road infrastructure on firms’ exports? As a byproduct and admittedly in a more indicative manner, we also tackle a second related question: If anything, how do these additional exports affect firms’ employment? In answering these questions, we use highly disaggregated firm-level export data from Peru that include firms’ inventories and sourcing patterns and performance of the formal manufacturing sector in India (see Datta, 2012 and Ghani et al. 2012, respectively); and households’ incomes in Nepal, Madagascar, and Indonesia (see Jacoby, 2006; Jacoby and Minter, 2009 and Gertler et al., 2014, respectively). As for Latin American countries, a recent paper investigates the impact of road access on the spatial distribution of population and economic activities across Brazilian municipalities (see Bird and Strazh, 2014).

1 With only a few exceptions (see, e.g., Gibbons et al., 2012 and Garcia López et al., 2013), most studies on developed countries focus on the United States. These studies examine the impact of transport infrastructure on: productivity (see Fernald, 1999); relative demand for skilled workers (see Michaels, 2008); suburbanization (see Baum-Snow, 2007); urban growth (see Duranton and Turner, 2012); counties’ earnings and market access (see Chandra and Thompson, 2000 and Donaldson and Hornbeck, 2016, respectively). Papers on developing countries primarily look at the experience of Asian and African countries. In particular, these papers assess the effects of transport infrastructure on: productivity (see Fernald, 1999); relative demand for skilled workers (see Michaels, 2008); suburbanization (see Baum-Snow, 2007); urban growth (see Duranton and Turner, 2012); counties’ earnings and market access (see Chandra and Thompson, 2000 and Donaldson and Hornbeck, 2016, respectively). Papers on developing countries have shown that improvements in transport infrastructure had a significant positive impact on firms’ exports and thereby on firms’ job growth.

2 Duranton et al. (2014) use plans for the United States’ Interstate Highway System, historical railroad networks and early exploration routes as instruments to estimate the effects of road infrastructure on international trade using micro data from a developing country as opposed to the more aggregated data utilized previously.3

3 There is also an incipient literature that looks at the impact of infrastructure across countries on economic outcomes (see, e.g., Feyrer 2009; Akerlund and Volpe Martincus et al., 2014).
the exact geographical origin of exports and the location of the ports through which each transaction exited the country in 2003 and 2010 along with detailed geo-referenced information on road infrastructure for Peru. In order to identify the effects of interest, we first exploit the spatial differences in the degree of exposure to the aforementioned infrastructure shock and the implied changes in transportation costs, and make use of the dimensions of our dataset to account for several potential confounding factors through diverse sets of fixed effects ranging from region-sector to firm-(region-sector) along with product-destination combinations. Second, we conduct placebo exercises and additionally use the Inca road network, the vast pre-Columbian transportation network that was built by the Inca Empire before 1530, as an instrument for the new transport infrastructure to further address the natural endogeneity concerns. To preview our main findings, estimation results indicate that domestic road infrastructure positively affected firms’ exports and this expansion in foreign markets induced firms to hire more employees.

In policy circles, domestic transport infrastructure is considered a key determinant of exports, which, in turn, are assumed to lead to more jobs. Statements in official documents introducing public export development programs of several countries are illustrative in this regard. The report presenting the United States National Export Initiative 2011 is a clear example. According to this report, “American businesses cannot participate in the global economy if they cannot get their products out the door. Deficiencies throughout America’s transportation system severely impact the ability of businesses to transport their goods to global markets. Now more than ever, America’s ability to support additional jobs here at home depends on the ability to export goods and services to the world.” This argumentative line is not exclusive of developed countries. In fact, for instance, in Peru, the Strategic National Export Plan 2003–2013 states “The exporting sector is one of the most affected by the infrastructure deficit, generally in transportation. [This sector] plays a fundamental role as a growth engine, in generating employment, and in fostering the development of nations.”

Evidence based on aggregate data indicates that such a link may exist between transport infrastructure, exports, and employment. Raw figures from Peru itself also point to the same direction. Exports from municipalities whose road connections to their main ports improved grew on average more than 150% over the period 2003–2010, while employment did it by 30%. Although suggestive, this kind of evidence is not informative of causality because there are potential endogeneity problems affecting both the relationship between internal infrastructure and exporting as well as that between exporting and employment. Thus, while road improvements might foster exports from regions targeted by infrastructure projects, it is equally possible that increasing foreign sales result in investments in these regions to reduce transport costs. In addition, there might potentially be unobserved factors correlated with road building that can also influence exports. For instance, topography can shape both the within-country spatial distribution of road infrastructure and economic activity and thereby that of exports (see, e.g., Ramcharan, 2009). Similarly, firms may hire more workers in response to additional demand from abroad or they may increase their number of employees to reach a scale that will make them later easier to deepen their penetration into foreign markets. Unfortunately, available evidence on to what extent infrastructure matters for exports is limited. In the same vein, whether these exports make a difference in terms of employment is far from clear.

We focus on Peru to fill this gap in the literature for several reasons. First, as mentioned above, road expansion in Peru was remarkable during the period under analysis. Specifically, more than 5000 kilometers of new roads were constructed in the country between 2003 and 2010, which roughly amounted to a more than 10% net expansion in the country’s main road network (see Cornejo Ramírez, 2010 and MTC, 2012). As shown in Fig. 1, to finance this expansion of the road network, public resources allocated to road infrastructure increased 610% (in nominal US dollars) to reach 1.3% of the country’s GDP in 2010 from its initial level of 0.5% in 2003 (see MEF, 2013). Second,

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5 There is a large number of studies showing that international transport costs have a significant negative impact on trade (see, e.g., Hummels, 2001; Limão and Venables, 2001; Clark et al. 2004; Blonigen and Wilson, 2008; Mesquita Moreira et al., 2008). See Behar and Venables (2010) for a useful survey of this literature.

6 From a political economy point of view, this would be more likely the case when exporting firms are relatively large as it could be in our case (see Section 2) and would therefore tend to have more bargaining power. As shown in Burgess et al. (2013), other political economy factors could also play a role (e.g., ethnicity).

7 It should be stressed, that according to the statistical information provided by the Peruvian Ministry of Transport and Communications (MTC), this expansion does not consist of mere bituminization of existing roads but net additions to the network of national and departmental roads. Besides these roads, there are local roads that are mostly non-paved and generally in bad shape (see MTC, 2005). As a consequence, they are not commonly used for international trade shipments. For further information see Volpe Martinecus et al. (2013).

8 According to official documents, the infrastructure plan pursued multiple simultaneous goals including decentralization, sustainable development, internal and external integration, and social inclusion (e.g., improve access to public services such as health and education particularly for poorer individuals living in more remote areas) (see MTC,

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Fig. 1. Evolution of the Total Length of the Road Network and Public Investment in Road Infrastructure. Source: Authors’ calculations based on data from MTC (2012) and MEF (2013). Length is measured in kilometers (red line, left axis). Investment is reported in millions of US dollars (black line, right axis) (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper).
new roads were asymmetrically distributed across regions in Peru. As a consequence, depending on the initial route(s) from the plants to ports, airports or borders used in exiting the country, available transport infrastructure increased and distance traveled and internal transport costs incurred diminished for some origins while those for others remained the same. Hence, by contrasting exports in both groups while controlling for potential confounding factors, we can, in principle, estimate the impact of this new infrastructure on firms’ exports. Fig. 2 provides a visualization of the most basic version of this differences-in-differences strategy at the municipal level. This figure shows that municipalities whose distance to the respective relevant ports shrank thanks to the new roads, experienced larger export growth (as measured by the non-conditional average log annual rate of change) than their counterparts whose distance to the reference ports remained constant over the period in which transport infrastructure expanded (2003–2010). Interestingly, both groups’ exports followed parallel trends before this period (1999–2002).5

Admittedly, a broad range of factors other than road infrastructure could have driven these developments. In our baseline estimations, we take advantage of our highly disaggregated geo-referenced export data to condition on an extensive set of fixed effects that account for differences over time across regions (i.e., departments) and sectors (i.e., 2-digit ISIC). In robustness checks, we control for differences across even more narrowly defined geographical units (i.e., provinces and municipalities), so that identification comes from the variation within these geographical units and activities.6 Results from these alternative estimations do not differ from the baseline. Another concern is that firms may have self-selected into locations over time and, as a consequence, firms located near the roads may be different from those in the rest of the country. Estimates from specifications that include firm(-region-sector) fixed effects to control for this potential firm heterogeneity also confirm our main findings.

In addition, we conduct a number of placebo exercises using georeferenced information on roads that were planned but had not been built by the end of our sample period and the timing and phase-in of transport infrastructure investments. We thereby accomplish our first and main task, namely, to obtain a consistent estimate of the effects of domestic transport infrastructure on exports while controlling for potential sources of endogeneity. Both ordinary least squares and instrumental variables estimates consistently suggest that new domestic roads have favored increased firms’ exports by primarily facilitating larger shipments.

Finally, available historical information for Peru allows us to combine our baseline difference-in-differences strategy with an instrumental variables approach as a complementary way to deal with endogeneity issues. In particular, we use the Inca road network as a conditionally exogenous source of variation in transport infrastructure. More specifically, we instrument the change in road infrastructure between 2003 and 2010 with two instruments: (i) the distance from the geographical origin of the exports to the nearest road that was part of the Inca network, and (ii) the distance between this origin and current port that could have been traveled along roads in this network. True, whereas this pre-Columbian network was clearly built up for reasons entirely disconnected with current foreign trade and—as we shall see below—it is a good predictor of current road infrastructure changes, it may be argued that these instruments might not completely fulfill the exclusion restriction. For example, the Inca roads may have been built in locations that were and are still important from an economic point of view or may have favored settlements that became urban centers that traded more in later centuries (see, e.g., Maloney and Valencia Caicedo, 2012). This would imply a correlation between these historical roads and current economic activity and trade performance across regions. We therefore also condition on the same alternative sets of fixed effects considered in the ordinary least squares estimations. While this helps reduce the risk that the Inca road network affects today’s exports through channels other than its correlation with the spatial allocation of new roads, it should be admitted that this strategy is not perfect because it cannot entirely preclude the possibility of such a violation of the exclusion restriction.

In order to achieve our secondary goal of assessing whether and how exports associated with infrastructure improvements influence employment, we use the predicted values from the estimated export equation as an instrument for the actual change in exports in an equation in which changes in employment are explained by changes in exports after conditioning by relevant covariates. Following this strategy, we find that the positive impact of domestic road infrastructure on firms’ exports has actually translated into employment generation.

Our analysis contributes to at least two different literatures. First, we add to the literature on the impact of infrastructure on trade. Within this literature, our paper is closer to the study by Volpe Martincus and Blyde (2013) that estimates the effects of domestic transport infrastructure on firms’ exports exploiting the earthquake that took place in Chile in February of 2010. We extend their analysis in several

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5 The t-test of differences in means indicate that average annual export growth of these two groups of municipalities are not significantly different from each other over the period 1999–2002 but became so over the period 2003–2010. (see notes in Fig. 2).

6 Peru is administratively organized in 25 departments. These departments are, in turn, subdivided into provinces (192 in total) comprising several municipalities (1841 in total). Municipalities are the smallest political-administrative division and are required to have a minimum of 3500 inhabitants. Lima is the capital city of the country and is located on the coast.
dimensions. First, due to data limitations, their estimated impacts are strictly short run whereas we look beyond an immediate response by considering a longer period.11 Second, their identification is based on a specific natural experiment, which provides credible quasi-random variation in infrastructure but makes it difficult to generalize and specifically check the external validity (see Redding and Turner, 2014). In contrast, we examine a more policy relevant case, namely, the expansion of a developing country’s road network, and address endogeneity by means of a different combination of identification strategies.

Third, we explore the general equilibrium effects that road expansion may have. More precisely, observed impacts could not only reflect new economic activity but also redistribution of this activity across units or agents. Given their different economic implications, which one prevails makes a substantial difference for the assessment of the policy under consideration. In order to disentangle actual changes from a redistribution of exports, we estimate separate equations comparing “treated” and “untreated” observations and “treated” and “residual” observations, as suggested by Redding and Turner (2014).12 These estimates reveal that infrastructure projects have had a net positive effect on exports. Finally, to the extent allowed by the data, we go beyond the impact on exports by tracing its subsequent implications for other economic outcomes, namely, firms’ employment.

Our second contribution, in this latter sense, is to the number of papers that examine the effects of exporting on firm performance while properly correcting for endogeneity. Within this extensive literature (see, e.g., Clerides et al., 1998; Bernard and Jensen, 1999; Girma et al., 2003; van Biesebroeck, 2005; De Loecker, 2007), our paper is methodologically closer to two recent contributions by Lileeva and Treder (2010) and especially Park et al. (2010). Lileeva and Treder (2010) investigate how exporting affected Canadian plants’ labor productivity and innovation between 1988 and 1996 by using plant-specific tariff cuts faced in the United States as an instrument for selling abroad. Similarly, Park et al. (2010) analyze the impact of exporting on Chinese firms’ productivity, employment, sales and other performance variables over the period 1995–2000. They instrument exporting with firm-specific exchange rate shocks based on the destination of firms’ exports before the Asian crisis.13 Unlike these papers, we examine -to our knowledge for the first time—the employment effects associated with increased exports driven by transport infrastructure improvements.

The remainder of this paper is organized as follows. Section 2 introduces the dataset and presents basic statistics and preliminary evidence. Section 3 discusses the impact of road infrastructure on exports. Section 4 examines the effect of exports on employment and its relationship with the road infrastructure changes, and Section 5 concludes.

2. Dataset and descriptive evidence

Our dataset consists of three main databases. First, we have highly disaggregated export data for 1999, 2002, 2003 and 2005–2010 from the Peruvian customs. Data are reported at the transaction level and cover the entire universe of transactions in those years. Specifically, each record includes the firm’s tax ID, the geographical origin of the flow (municipality), the product code (HS 6 digit), the port, airport or land border (hereafter generically “ports”) through which the good

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<td>Municipality’s share of urban population</td>
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<td>Department-2 digit ISIC sector fixed effect Observations</td>
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Source: Authors’ calculations based on data from SUNAT and MTC. The first two panels of the table characterize both aggregate exports of differentiated goods (upper panel) and the average exporter of differentiated goods (lower panel). Goods are classified as differentiated using the conservative version of the classification proposed by Rauch (1999). Total aggregate exports are expressed in millions of US dollars. Average firm total exports are expressed in thousands of US dollars. The bottom panel of the table presents estimates of an equation in which the dependent variables are the natural logarithm of the export value, the natural logarithm of the export weight, the natural logarithm of the number of shipments, the natural logarithm of the distance to Callao (Peru’s main port and airport), the natural logarithm of the firms’ number of employees, the natural logarithm of the firms’ age, the natural logarithm of the municipality’s height, the natural logarithm of the municipality’s population, the natural logarithm of the municipality’s population density, and the municipality’s share of urban population at the level of the data used in the main estimation (i.e., firm-product-destination) in 2003 and the main explanatory variable is a binary indicator that takes the value of one if the distance to the main port declined for the observation in question between 2003 and 2010 and zero otherwise. Department-2 digit ISIC sector fixed effects included (not reported). Standard errors clustered by department are reported in parentheses below the estimated coefficients. Significant at the 10% level; “*” Significant at the 5% level; “**” Significant at the 1% level.

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11 Strictly speaking, given the length of our sample period, estimates are likely to capture medium term effects. Some of the papers investigating the relationship between roads and other economic outcomes are able to consider longer time periods and thereby provide estimates that would be more representative of long term effects (see, e.g., Bann, Snow, 2007 and Michaels, 2008).

12 We followed Redding and Turner (2014) by defining “untreated” observations as those observations that are physically and economically close to their counterparts “treated” with increased infrastructure and thus potentially exposed to externalities; and “residual” observations as the remaining ones.

13 Brambilla et al. (2012) use the exogenous changes in exports and export destinations associated with the 1999 Brazilian devaluation to identify the causal effect of exporting and of exporting to high-income countries on skill utilization by Argentinian manufacturing firms.
exits Peru, the destination country, the export value in US dollars, and the quantity (weight) in kilograms. Hence, for each firm, we know the geographical origin of their exports, the export value, the quantity shipped, the number of shipments, and the exiting port for each of its product-destinations. We should mention herein that the sum of these firms’ exports virtually adds up to the total merchandise exports as reported by the Central Bank of Peru, with the annual difference being always less than 1%. In the analysis below we focus on exports of differentiated products as defined according to the classification proposed by Rauch (1999). The reason is that these products are mainly transported by road. In contrast, transport modes other than roads account for a non-negligible and even relatively important share of natural resources—specifically minerals and metals— and primary products’ total cargos (see MTC, 2005). Second, we have firm-level data on employment, sector of activity, and starting date from Peru’s National Tax Agency, SUNAT. The first panel of Table 1 presents a snapshot of Peruvian total exports of differentiated goods in 2003 and 2010—which will be the initial and final sample years in our econometric analysis—along with key export extensive margin indicators. Exports of differentiated goods grew more than 120% between these years to reach 3.1 billion US dollars in 2010. These foreign sales expanded along the firm, destination, and product extensive margins. Thus, the number of firms, destination countries, and exported products increased by 42.5%, 3.4%, and 6.5% from 2003 to 2010, respectively. Yet, most of the expansion is accounted for by a larger intensive margin on the product-country dimension, i.e., larger average exports by product and country. This was the result of both larger average shipments and a larger number of shipments, which rose nearly 135%. These shipments exited the country through 15 ports. The second panel of Table 1 characterizes the average Peruvian exporter of differentiated products in these years. On average, in 2010 exporting firms had 82 employees and sold 9.7 billion dollars worth of exports. Fig. 3. Road Networks in 2003 and 2010. The Inca Road Network. Improvements in Current Road Networks and the Inca Road Network. Source: Authors’ calculations based on data from MTC, ArcGIS, and Regal (1936). Left Panel: The 2003 (national and departmental) road network is colored in grey, whereas the additions to this network between 2003 and 2010 are colored in black. Middle Panel: The Inca Road Network appears in red. Right Panel: The additions to the (national and departmental) road network between 2003 and 2010 are colored in black. The Inca Road Network appears in red (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper).

Fig. 4. Distribution of Distances to Main Ports, 2003 and 2010. Source: Authors’ calculations based on data from SUNAT, MTC, and ArcGIS. The figure is a quantile-quantile graph that plots the quantiles of the distances traveled (in kilometers) from the plants to the exiting ports at the beginning and at the end of the sample period for exports that are positive in both periods.
products to 2.3 countries for approximately 1.8 million US dollars. In selling abroad, each of these firms made 94 annual shipments.

Third, the Peruvian Ministry of Transport and Communications (MTC) kindly provided us with geo-referenced versions of the maps of the Peruvian road (national and departmental) networks in 2003 and 2010 (see the left panel of Fig. 3). Assuming that profit-maximizing firms minimize the distance traveled between any two observed shipping locations, we are able to determine both the domestic route(s) that each firm originally used from the production facilities to the exporting ports in shipping each of their products to each of their destination countries and the routes utilized after new roads were built. We identified these routes following a method that makes use of spatially geo-referenced data on the road network (see, e.g., Combes and Lafourcade, 2005).17

The average exporter was located 252.9 km away from its main port in 2003. With road infrastructure improvements in place, the average distance to the main ports declined around 10% from 2003 to 2010.18 Note that this is an average across all exporters, i.e., taking into account both those with changed and unchanged shipping distances. If we instead consider only those roughly 800 firms that could actually use shorter-distance routes thanks to the new roads (see Table 1), this reduction more than doubles to reach 22.1%. Fig. 4 shows the entire distribution of distances traveled between production plants and exit nodes at the beginning and the end of the sample period. This figure reveals that innovations to the road infrastructure caused an important shift in the distribution of distances and, predictably, a reduction in domestic transport costs.

In Fig. 5, we compare non-parametrically the unconditional average annual growth rates of exports whose distances to the main port decreased with that of their counterparts whose distances remained the same both for 1999–2002 (i.e., the period before roads were built) and 2003–2010 (i.e., the period during which roads were built). This figure suggests that, while the former experienced average larger expansions than the latter over the period 2003–2010, they do not seem to differ from each other over the period 1999–2002. More specifically, according to the procedure proposed by Delgado et al. (2002), the distribution of the annual growth rates of exports with declining distances stochastically dominates that of the exports with invariant distances in the second period, but does not significantly differ from the latter in the first period.19

The third panel of Table 1 compares observations that correspond to cases of improvements in road infrastructure over the period 2003–2010 and observations that correspond to cases of no infrastructure changes over this period in terms of a number of relevant geographical and economic characteristics. This is done conditioning on department-sector fixed effects, which we later include in our baseline estimating equation. Estimates reveal that, once department and sector differences are accounted for, both groups do not seem to have been initially different from each other.

As discussed above, we also resort to instrumental variables estimation. In this sense, we have obtained digital images of maps of the different portions of the Inca road network (see Regal, 1936) and have converted these images into a digital map with the same format and projection as the maps of the 2003 and 2010 road networks (see the middle panel of Fig. 3). Based on this map, we construct the two variables that will be used as instruments in our estimations: the distance from each municipal capital to the Inca road network and the distance that could have been traveled on this network between any given two locations in Peru.

17 More precisely, we apply a method based on a Geographic Information System (GIS). This system consists of a digitalized real transport network that connects the country’s municipalities with each other, including those where ports are located. The network is composed of several arcs that correspond to the different types of roads belonging to the road system (i.e., highways, primary roads, and secondary roads). The Arc View program is used to identify the least-distance itinerary between each municipality of origin and each port, whereby this distance is calculated by adding up the different arcs that connect the respective intermediate end-nodes (see Volpe Martincus and Blyde, 2013).

18 The distribution of the share of each Peruvian department in the total number of exporters whose connection with their respective main port improved as consequence of the new roads and that of their share in the total number of peers not experiencing any change in this regard across Peruvian departments resemble each other. In fact, according to the Kolmogorov–Smirnov test, these distributions are not significantly different from each other. More specifically, combined test statistic is 0.294 and the corresponding p-value is 0.454.

19 See notes in Fig. 5.
3. Domestic road infrastructure and exports

3.1. Estimation approach

We aim at estimating the effects of domestic road infrastructure on exports. Clearly, as mentioned above, there are factors other than this infrastructure that may affect firms’ foreign sales. Thus, these sales may be larger because of higher firm productivity or other public policies. Failure to properly account for these other factors would result in biased impact estimates. Our baseline empirical model of exports therefore includes appropriate sets of fixed effects to control for such factors. We specifically postulate the following export equation:

$$\ln X_{frpc}(t) = aD_{frpc}(t) + \delta_{frs}(t) + \theta_{frp}(t) + \epsilon_{frpc}(t)$$

(1)

where $f$ denotes firm, $r$ stands for region (Department), $s$ indicates sector (2-digit ISIC), $p$ corresponds to product, $c$ refers to destination country, and $t$ indexes year. The main variables are $X$ and $D$. The former represents export value. The latter, $D$, is a binary indicator that takes the value of 1 if firm located in region $r$ and belonging to sector $s$ uses a shorter distance route to ship product $p$ to the respective main port through which it exports to destination country $c$ and 0 if it uses a same-distance route. In other words, our main explanatory variable captures whether distance to the port declined and accordingly access to a shorter distance route. In other words, our main explanatory variable captures whether distance to the port declined and accordingly access to a shorter distance route.

Two considerations are worth making in this regard. First, we use a binary indicator in our benchmark specification because it imposes less parametric structure than a linear relationship between distance to ports and exports.

In this sense, note that topography can create important non-linearities. This holds particularly true for Peru, which is the third roughest country in the world, only surpassed by China and Nepal (see Ramcharan, 2009). Second, distance to the main port is utilized since most firms just use one port in shipping a given product to a given destination. In fact, while firms can and do use different ports depending on the specific product-destination combinations, the average (median) number of ports per firm-product-country is 1.02 (1).

The remaining terms of Eq. (1) correspond to control variables. Thus, $\delta_{frs}(t)$ is a set of firm-region-sector-product-country fixed effects that captures, for instance, the firm’s knowledge of the market for a given product in a given country; $\theta_{frp}(t)$ is a set of region-sector-year fixed effects that absorb the influence of region-sector shocks such as, for example, changes in other public policies aimed at promoting exports in specific regions or sectors (see, e.g., Volpe Martincus, 2010) as well as changes in foreign demand for goods produced by firms in particular sectors that are primarily concentrated in certain regions; and $\epsilon_{frpc}(t)$ is the error term.

In estimating Eq. (1), we use differencing to eliminate the firm-product-country fixed effects.21 Further, by aggregating time series information into two periods 2003 and 2010, we address the serial correlation problem to which equations such as ours are typically subject (see Bertrand et al., 2004). In particular, we estimate the following baseline equation:

$$\Delta \ln X_{frps}(t) = aD_{frps}(t) + \delta_{frs} + \epsilon_{frps}$$

(2)

where $\Delta \ln X_{frps}$ is $[\ln X_{frps}(2010) - \ln X_{frps}(2003)]/7$ is the average annual log change in exports; we already have taken into account that

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20 Notwithstanding, we also estimate our model under a linear relationship between distance to ports and exports as a robustness check (see Table 2). Similarly and in the same vein, we also consider a specification based on distance reduction bias (see Table 2) to relax our binary specification.

21 When the number of periods is equal to two, first-differencing and fixed effect estimation produce identical estimates and inference (see Wooldridge, 2002).
3.2. Baseline results

Column 1 of Table 2 presents ordinary least squares estimates of Eq. (2). The coefficient of interest is positive and statistically different from zero. In particular, according to the point estimate, the average annual rate of growth of those exports whose routes to the main port experienced a reduction in their length due to the construction of new roads has been 3.8% higher than that of their counterparts whose route length remained the same over the period 2003–2010. In assessing the significance of the effects, we consider standard errors clustered by department to account for potential correlation of exports stemming from the same region.

Given that the average (logarithmic) distance traveled to the exit point would have decreased by 22.1% for trade flows with shorter distances and that the estimated ordinary least squares coefficient on the long differences (2003–2010) is 0.259, the distance elasticity of exports would be roughly 1.2. This is similar to the estimate reported in Volpe Martincus and Blyde (2013), but it is larger than that estimated by Duranton et al. (2014). Note, however, that the latter estimate corresponds to domestic trade and are obtained from data at a higher aggregation level (i.e., region-pair level instead of firm-product-country level). Moreover, unlike the former study, our estimated elasticity informs the effect of new roads as opposed to existing roads (or their disappearance) in a country with much more limited transport infrastructure.

A simple back-of-the-envelope calculation based on the estimated impact of infrastructure on the 2003–2010 export growth reveals that, in the absence of changes in domestic road infrastructure, total exports of differentiated goods would have been roughly 5.6% smaller in 2010. Taking into account that annual average public investment in road infrastructure over the period 2003–2010 was approximately USD895 million, this implies that additional exports of differentiated goods alone would have amounted to more than 17% of such average investment in just one year.

In our basic specification increased road infrastructure is captured by a binary indicator. Thus, the estimated coefficient on this variable gives the effect associated with the infrastructure treatment status. Assuming that the intensity of this treatment can be proxied with the change in raw distances to the main port between 2003 and 2010 as computed according to the method referred to above, we can re-estimate Eq. (2) using this plain distance change as the main explanatory variable. Alternatively, we can assume a more flexible functional form whereby reduced distances to ports are allowed to have different effects on exports depending on their size but in discrete intervals. In particular, we can also estimate a variant of Eq. (2) using as main explanatory variables three binary indicators that correspond to three distance reduction bins: up to the 25th percentile, between the 25th and 75th percentile, and above the 75th percentile. Estimates of these modified equations are presented in the second and third columns of Table 2, respectively. Both estimates point to the same direction and indicate that the impact is stronger the larger is the reduction in the distance to ports made possible by the new roads. Noteworthy, the direct estimated distance elasticity is comparable to that implied by our baseline estimation results. We next go through several robustness checks.

3.3. Robustness checks

3.3.1. Stricter fixed effects

While our baseline specification includes region-sector fixed effects and thus isolate the influence of regional-sectoral level confounders, there may be other factors that can also potentially play a role in explaining exports which differ within region-sector pairs. This is for instance the case with geography, level of development, and sectoral structure in terms of economic activities. Hence, we also estimate variants of Eq. (2) including fixed effects that control for differences across lower level geographical units such as provinces and municipalities in combination with sectors of activity. In this regard, notice that the median Peruvian municipality is relatively small (208 squared kilometers or 81 squared miles), so that systematic differences in terms of geography or level of development relevant for exporting are less likely to prevail within these jurisdictions. Further, if local differences existed in terms of natural endowments (e.g., land quality) and expressed themselves in diverging economic structures across areas within these districts, the municipality-sector fixed effects included in one of the specifications can contribute to isolate them. Ordinary least squares estimates of these alternative export equations, which are obtained by strictly exploiting the variation within province-sector and municipality-sector, are presented in Columns 1 and 2 of Table 3 and confirm the baselines.

While this battery of fixed effects goes a long way in controlling for potentially relevant unobserved factors, identification problems related to such kind of factors cannot be considered ruled out. Thus, for instance, while Peruvian municipalities are not large, they can still be big enough to host areas with geographical and economic characteristics that differ in such a way that municipality-sector fixed effects are not able to account for differences between sub-localities with improved road access to ports and their counterparts without changes in road infrastructure. More generally, other so far omitted, even more granular factors may have played a role in explaining the expansion of firms’ foreign sales. Further, as referred to before, firms may self-select in locations and those close to main roads may be different from their counterparts located elsewhere along relevant dimensions. Thus, we have estimated variants of Eq. (1) that include location-sector linear trends using data for 1999, 2003, and 2010. Estimates from these equations confirm our baseline results (see Table A.2.1 in the online Appendix).

This result remains robust to clustering standard errors by province and municipality (see Table A.3.1 in the online Appendix). Even though there are relatively few of them, we prefer to be conservative and cluster standard errors by department instead of the alternatives because exports are likely to be correlated across provinces and municipalities given their relatively small size and similar specialization.

As shown in the left panel of Fig. 3, almost no roads were built in the Selva (tropical rain forest) region (see Volpe Martincus et al., 2013). In an alternative estimation we have accordingly excluded observations that correspond to firms shipping goods from departments belonging to this region. Estimates are robust to removing these observations. Results from these estimations are included in Table A.4.1 in the online Appendix.

This figure should be seen as a lower bound as only a portion of the aforementioned resources was actually invested in the construction of new roads. Part of these resources was allocated to maintenance, repairing, and rehabilitation of roads.
exports from the former may have grown because of increased firm productivity or because of larger demand for particular goods from particular importing countries associated with a decline in the respective transport costs or tariffs applied thereon (see, e.g., Volpe Martincus and Blyde, 2013). Moreover, firms exposed to infrastructure improvements may have also received support from Peru’s national export promotion organization -PROMPERU- to participate in trade missions and international marketing events leading to foreign sales, in which case we would be overestimating the effect of interest (see, e.g., Volpe Martincus and Carballo, 2008).

In order to control for these additional potential confounding forces and hence check the robustness of our previous estimation results, we include sets of fixed effects along the respective dimensions in the equation estimated on the disaggregated export data. More precisely, we also estimate alternative specifications in which we include firm fixed effects, destination and product fixed effects, and product-destination fixed effects. In the most demanding variant, we incorporate firm and (HS 2 digit) product-destination fixed effects, so that

effects are identified based on the variation within firms in given locations across (HS 2 digit) product-destination combinations and within (HS 2 digit) product-destination combinations across firms. Ordinary least squares estimates of these augmented export equations are reported in Columns 3–6 of Table 3. Reassuringly, these estimates essentially corroborate our initial findings based on the baseline specification.

3.3.2. Placebo exercises and heterogeneities

In this subsection we assess the robustness of our results by performing four checks that consist of three placebo tests and an assessment based on heterogeneities. First, if our identification strategy is correct, we should not see differences in exports in absence of changes in road infrastructure. Using export data for 1999 and 2002 we carry out a falsification exercise in which we assume that the new roads

30 Product-destination fixed effects might also likely account for potential positive export information spillovers from firms with improved road connections with their main ports to peers without changes in these connections, thus mitigating the risk of underestimating the effect of interest.

31 In our data a firm fixed effect is equivalent to a firm-region-sector (i.e., firm-department-2 digit ISIC) fixed effect.

32 There might have occurred shocks to input provision that might have differented effects on production across goods or changes in firms’ competencies across them. Unfortunately, we cannot estimate the specification including firm-product and product-destination fixed effects because this model is overparametrized. Nevertheless, we believe that the estimation results shown in Table 3 provide sufficiently convincing evidence that road infrastructure improvements have positively affected exports.

Table 3
The impact of new roads on firms’ exports, 2003–2010
Robustness check
Alternative specifications—OLS estimates

<table>
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<td>0.241</td>
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<td>0.243</td>
<td>0.241</td>
<td>0.242</td>
<td>0.241</td>
</tr>
</tbody>
</table>

| Observations                           | 5415  | 5415  | 5415  | 5415  | 5415  | 5415  |

Source: Authors’ calculations based on data from SUNAT and MTC. The table reports OLS estimates of Eq. (2). The dependent variable is the change in the natural logarithm of export value at the firm-product-country level between 2003 and 2010. Exports consist exclusively of differentiated goods.30 In the most demanding variant, we incorporate firm and (HS 2 digit) product-destination fixed effects, so that

unfortunately, we cannot estimate the specification including firm-product and product-destination fixed effects because this model is overparametrized. Nevertheless, we believe that the estimation results shown in Table 3 provide sufficiently convincing evidence that road infrastructure improvements have positively affected exports.
were constructed between 1999 and 2002 instead of between 2003 and 2010.\textsuperscript{33}\textsuperscript{33} This amounts to test whether exports shipped along shorter routes and exports whose routes did not change in more recent years followed parallel trends before the new roads were constructed. Estimation results are shown in the upper panel of Table 4. Notice that, for comparison purposes, we include estimates for the period 2003–2010 when we restrict the sample to those firm-product-destination triples that are also present in the former sample and, in both cases we use average annual growth rates which accounts for the different length of the sample periods. According to these results, no pre-policy differences in trajectories appear to have prevailed.\textsuperscript{34}

Second, available information on transport infrastructure plans and the associated changes in distances to ports that would result from implementing these plans can be used to conduct an alternative falsification exercise that provides additional validation for our findings. More specifically, a recent road inventory in Peru indicates that there were more than 2000 kilometers of projected, not yet built national roads (i.e., roughly 10% of the total length of the national road network) which could be considered comparable to those roads those were more than 2000 kilometers of projected, not yet built national roads (i.e., roughly 10% of the total length of the national road network) which could be considered comparable to those roads those were more than 2000 kilometers of projected, not yet built national roads (i.e., roughly 10% of the total length of the national road network) which could be considered comparable to those roads those were more than 2000 kilometers of projected, not yet built national roads (i.e., roughly 10% of the total length of the national road network) which could be considered comparable to those roads those were more than 2000 kilometers of projected, not yet built national roads (i.e., roughly 10% of the total length of the 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roughly 10% of the total length of the national road network) which could be considered comparable to those roads those were more than 2000 kilometers of projected, not yet built national roads (i.e., rough...
road investments as an alternative assessment of our identification approach.37 This is precisely what we do in the lower panel of Table 4, where we utilize export data for intermediary years to estimate Eq. (2) over two different time windows, 2003–2006 and 2006–2010. As with the previous exercise, the dependent variables are then the respective average export annual growth rates. In addition to the baseline case, estimates are only significant when the later years of our sample period are included, i.e., 2006–2010. This provides further evidence in favor of a causal interpretation of our estimated effects.

Heterogeneities can also inform identification because they can provide evidence on the specific mechanisms by which a variable affects an outcome (see Rajan and Zingales, 1998). In our case, a natural dimension to look for these heterogeneous effects is product categories. In particular, transport infrastructure is likely to favor foreign sales of heavy products more than those of their light counterparts. Table 5 presents estimates of Eq. (2) for these different types of products. Consistent with the priors, estimates indicate that effects were stronger for heavier goods (i.e., goods whose initial weight to value ratio were above the median) than for lighter goods (i.e., goods whose initial weight to value ratio were at or below the median).38

3.3.3. The Inca roads as instruments

As discussed in the Introduction, the obvious challenge we face in identifying the effect of road infrastructure on exports is that the former can be endogenous to the latter either because of missing variables that may drive both spatial allocation of new routes and exports or because new roads may have been constructed based on expected future trade. In the analysis below we apply an instrumental variables approach on top of the difference-in-differences strategy as an alternative means to address endogeneity concerns.

Specifically, we use instrumental variables to estimate our export equation on firm-(region-sector)—product—destination data expressed in differences —which allows us to primarily account for time-invariant factors at this level—and that additionally includes region-sector fixed effects. In so doing, we exploit the Inca road system, a network of several thousand kilometers of routes whose origins can be primarily traced back to the mid-fifteenth century (see Section A.1.2 in the online Appendix for detailed information on the characteristics of this road system). More precisely, we instrument the change in available road infrastructure (i.e., new road construction leading to reduced distance traveled) with two variables that measure the accessibility to and the coverage of the Inca road network, namely, the distance from the geographical origin of the export flow to the nearest road that was part of the Inca network and the distance that could have been traveled along these roads between the origin and the current port through which this flow leaves the country, respectively.39 More formally, we estimate the following first-stage equation40:

\[ D_{y_{ps}} = \delta \ln(\text{Dist. to Inca Roads})_{y_{ps}} + \rho \ln(\text{Dist. on Inca Roads})_{y_{ps}} + \gamma_{ts} + \epsilon_{y_{ps}} \]  

(3)

These variables are valid as instruments as long as they predict recent road infrastructure improvements, but are otherwise uncorrelated with exports. This involves two conditions. First, these variables must be partially correlated with infrastructure innovations once the other relevant variables have been netted out. As suggested in Fig. 3 (right panel), our both instruments are very likely to predict the evolution over time of the modern road network. The direction of the relationship, however, can a priori go in either way. On the one hand, similar to the United States exploration routes, the Inca roads resulted from a search for an easy way to get from one place to another place on foot or animal-back. Since a good route for a man or an animal can be assumed to be also good for a car, the Inca roads will often goood routes for contemporary highways (see Duranton et al., 2014). In such a case, we would expect a negative correlation between infrastructure improvements and distance to the Inca road network and a positive correlation between infrastructure improvements and the distance that could have been traveled on this network between two locations. On the other hand, it may also be perfectly possible that, while first, older roads were already constructed following the trace of and thus overlapped with the Inca road network, newer, more recent roads may be build in regions that are less developed in terms of infrastructure and farther away from where the Inca road network was. Here, a positive correlation between infrastructure improvements and distance to the Inca roads would prevail.

Second, the variables chosen as instruments must be uncorrelated with the error term, i.e., they must be exogenous, which requires to properly accounting for factors that influence exports and are correlated with both the access to and the extension of available Inca roads. In this sense, the construction of the Inca roads had no association with past overseas trade, which was virtually nonexistent. Several researchers coincide in that the closed and family character of the Incas’ economic organization did not even create room for markets and domestic trade.41 In particular, within this organization each family produced what was needed for subsistence and, if any, domestic trade was extremely restricted to specific products (see Romero, 1949; D’Altroy, 1992 and Murra, 2002).42 This system sharply contrasts with that prevailing in other Latin American pre-Columbian Civilizations such as the Aztecas where domestic trade played a much more preponderant role. Among other things, this scheme was possible due to the notorious local ecological diversity of the area that currently corresponds to Peru, which allowed inhabitants of specific regions to have access to a broad variety of natural products without the need to resort to cross-regional exchanges (see Arciniegas, 1990 and Contreras, 2010).43

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37 Regrettably we do not have infrastructure data for intervening years but only for the period's end points, 2003 and 2010.
38 It might also be the case the firms with more access to external or internal finance are in better position to take advantage of the reduction in transportation costs to expand exports. Unfortunately, we cannot test the potential conditioning influence of access to external finance because we lack data on standard proxies such as proximity to banks or specificity of the collateral the firms use. As for access to internal financing, in absence of information on variables such as cash or de facto debt, we use firms’ age as a proxy. In particular, we allow for different estimated export effects of road infrastructure depending on whether firms’ age is above or below the median in the year the infrastructure investments started to pick up, 2006 (8 years). Estimated impacts do not significantly differ between the different age groups. Keeping in mind the limitations of age as a proxy, this would suggest that internal financing did not play an important role as a source of heterogeneous export responses (see Table A.9 in the online Appendix).
39 For firms off the Inca road network, distances on this network are computed from the point that would have been closest to the municipalities from which their export flows are shipped.
40 Even though the treatment variable is binary, a linear model is used to estimate the first-stage equation. The reason is that linear 2SLS estimates have a robust causal interpretation that is insensitive to the possible nonlinearity of the first-stage conditional expectation function (see Angrist, 2001, 2006).
41 There was no currency in the Inca Empire (see Rodríguez, 1977; and Arciniegas, 1990). One of the most often cited and highly regarded sources of information about the Inca civilization are the memoirs of Polo de Ondegardo, a Spanish Kingdom representative, who arrived to the Andean region in 1546 and was in charge of supervising Incas’ activities. In his records there is no single mention to the existence of markets or merchants (see Romero, 1949).
42 According to Murra (2002), the Incas implemented a system whereby each family group simultaneously had parcels located in different areas, which allowed them to have access to diverse crops. Kinship as well as military and religious ties guaranteed production sharing.
43 While Hartmann (1968) argues that some domestic trade took place in the North of the Empire, later revisions by Oberem (1978) and Salomon (1978) challenge this view and unambiguously conclude that, if present at all, trade was very limited and developed at a very late stage. The thesis that postulates the existence of markets and trade was also questioned by Noyez (1995). The most relevant reference to internal trade corresponds to the exchange of a shell called the mullu, which was considered a holy object able to attract the rain (see Rostworowski, 1970). The mullu was collected in the South coast of Peru and the artisans who sculpted the mollusks periodically traveled to Cuzco.
This critical value corresponds to the bias cutto middle 2003 and 2010 as a consequence of the new roads built in this period and zero otherwise. The latter is instrumented with the distance from the geographical origin of the export variable is a binary indicator that takes the value of one if the distance over which a.

Furthermore, the Inca road network can hardly be considered to have been designed to facilitate today’s exports. The mere length of time and the fundamental political, economic, and social changes occurred since the Inca era speaks in favor of using it for instrumentation purposes. The shifts in economic geography are a testimony to that fact. Thus, while Cuzco was the core of the Inca Empire, with the establishment of the Spanish colony the political and economic center moved to Lima, Peru’s current capital city (see the middle panel of Fig. 3). This created an entirely new spatial and transport dynamics as goods started to be shipped from Lima (goods coming from Spain consumed by local authorities and settlers) and to Lima (goods going to Spain, primarily precious metals) (see Contreras, 2010).

Table 6 presents instrumental variables estimates of Eq. (2), estimates of Eq. (3) along with variants thereof whereby only one of the two Inca road network-related variables are indeed correlated with recent innovations in transportation infrastructure.44 Consistently, according to the Kleinbergen–Paap (KP) test statistic, our overidentifying restrictions cannot be rejected from a weak instruments problem.

### Table 6

| Source: Authors’ calculations based on data from SUNAT and MTC. The table reports IV estimates of alternative specifications of Eq. (2) along with estimates of Eq. (3) and the relevant specification test statistics for the latter. The dependent variable is the change in the natural logarithm of export value at the firm-product-country level between 2003 and 2010. Exports consist exclusively of differentiated goods.
|---|
| **Table 6** The impact of new roads on firms’ exports, 2003–2010

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<td><strong>Distance on the Inca Road</strong></td>
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</tr>
<tr>
<td><strong>(0.016)</strong></td>
</tr>
</tbody>
</table>

| **(footnote continued)** although they never actually “sold” them (see, e.g., Murra, 2002). |

| **Department-2 digit sector fixed effects** | Yes | Yes | Yes | No | No | No | No | No |
| **Province-2 digit sector fixed effects** | No | No | No | Yes | No | No | No | No |
| **Firm fixed effects** | No | No | No | No | Yes | Yes | Yes | Yes |
| **HS 2 digit product fixed effects** | No | No | No | No | No | Yes | Yes | Yes |
| **Destination fixed effects** | No | No | No | No | No | No | Yes | No |
| **HS 2 digit product-destination fixed effects** | No | No | No | No | No | No | Yes | No |

| **[0.000]** | **[0.000]** | **[0.000]** | **[0.000]** | **[0.000]** | **[0.000]** | **[0.000]** | **[0.000]** | **[0.000]** |
| **KP test statistic** | 23.302 | 28.311 | 36.759 | 53.434 | 29.808 | 66.179 | 82.692 | 80.954 | 83.273 |
| **[0.000]** | **[0.000]** | **[0.000]** | **[0.000]** | **[0.000]** | **[0.000]** | **[0.000]** | **[0.000]** | **[0.000]** |
| **Hansen test statistic** | 0.482 | 0.681 | 0.851 | 0.921 | 2.444 | 1.771 | 0.007 | **[0.048]** | **[0.049]** | **[0.356]** | **[0.337]** | **[0.118]** | **[0.183]** | **[0.956]** |
| **Observations** | 5415 | 5415 | 5415 | 5415 | 5415 | 5415 | 5415 | 5415 | 5415 | 5415 | 5415 | 5415 | 5415 |

**Table 6** presents instrumental variables estimates of Eq. (2), along with estimates of Eq. (3) and the relevant specification test statistics for the latter. The dependent variable is the change in the natural logarithm of export value at the firm-product-country level between 2003 and 2010. Exports consist exclusively of differentiated goods. Goods are classified as differentiated using the conservative version of the classification proposed by Rauch (1999). The main explanatory variable is a binary indicator that takes the value of one if the distance over which a firm shipped their products to their main port when exporting to a given country declined between 2003 and 2010 as a consequence of the new roads built in this period and zero otherwise. The latter is instrumented with the distance from the geographical origin of the export flow to the nearest Inca road and/or the distance that could have been traveled along the Inca road network from this origin to the port through which the firm exports the product to the destination country. Alternative sets of fixed effects (i.e., Department-2 digit ISIC sector; Province-2 digit ISIC sector; Municipality-2 digit ISIC sector; Firm; Firm and HS 2 digit product; Firm, HS 2 digit product, and destination; Firm and HS 2 digit product-destination) included (but not reported). Standard errors clustered by department are reported in parentheses below the estimated coefficients. Test statistics and p-values based on these clustered standard errors are presented in the lower panel. The Hausman test cannot reject the null hypothesis that the GLS and the IV estimates are the same. The chi-square statistics is 2.060 and the corresponding p-value is 0.152. * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

44 This critical value corresponds to the bias cutoff method for a 10% maximal bias.
rejected.\textsuperscript{45} We have also computed the fractionally resampled Anderson–Rubin test for the significance of endogenous regressors in an instrumental variables regression proposed by Berkowitz et al. (2012). This test makes it possible to conduct reliable inference when instruments are nearly exogenous but not necessarily perfectly exogenous. According to this test, the null hypothesis that the impact of infrastructure on exports is equal to zero is rejected at 5% (with a $p$-value ranging from 0.032 to 0.014 for resampled fractions between 0.20 and 0.25, respectively).\textsuperscript{46}

The instrumental variables estimate of the coefficient of interest is positive and significant.\textsuperscript{47} This estimated coefficient is larger than the ordinary least squares counterpart. The same results pattern holds in several related studies (see, e.g., Baum-Snow, 2007 and Duranton and Turner, 2012). Notice, however, that, in our case, a Hausman test indicates that ordinary least squares and instrumental variables estimates are not significantly different from each other.\textsuperscript{48}

A major concern with these instrumental variable estimates is that the exclusion restriction may not hold. Thus, it might be argued that regions or cities that were large and productive in the Inca times and got a better access to the road network are still today large and productive and, accordingly, tend to export more or that there are geographical factors that may be correlated with both the Inca road network and production and exports (see, e.g., Ramcharan, 2009).\textsuperscript{49} In this sense, note, first, that while there seems to be some relationship between relevant municipality-level variables such as population, population density, and the share of urban population and the Inca Roads variables, no association at all is observed in our sample after conditioning by region fixed effects as we do in our baseline estimations.\textsuperscript{50} Second, to further mitigate this concern, we re-estimate the alternative specifications of the export equation that include province or municipality fixed effects combined with sector fixed effects or firm(-region-sector) fixed effects with our instrumental variables procedures. Estimation results are presented in Columns 4–9 of Table 6 and corroborate those shown before.\textsuperscript{51}

Third, the variables related to the Inca road network might be specifically better at predicting road constructions that are important for exports. Nevertheless, the estimated coefficient of the first-stage equation as estimated on the subsample of exporting municipalities does not significantly differ from the counterpart estimated on the subsample of never exporting municipalities.\textsuperscript{52} Finally, the road network in Peru consists of national and departmental roads, which have different purposes. Thus, national roads interconnect the country

\begin{table}[h]
\centering
\caption{The impact of new roads on firm exports, 2003–2010 OLS estimates}
\begin{tabular}{lcc}
\hline
& Channels & \\
\hline
\multicolumn{2}{c}{Log quantity (Kg)} & \\
D & 0.028$^{\ast}$ & (0.008) \\
\hline
\multicolumn{2}{c}{Log unit value (US Dollars per Kg)} & \\
D & 0.005 & (0.006) \\
\hline
\multicolumn{2}{c}{Log number of shipments} & \\
D & 0.006 & (0.005) \\
\hline
\multicolumn{2}{c}{Log average exports per shipment (US Dollars)} & \\
D & 0.030$^{***}$ & (0.006) \\
\hline
\multicolumn{2}{c}{Log average quantity per shipment (Kg)} & \\
D & 0.034$^{***}$ & (0.008) \\
\hline
\multicolumn{2}{c}{Department-2 digit sector fixed effects} & \\
Observations & 5415 & \\
\hline
\multicolumn{2}{c}{Firm export extensive margin} & \\
D & 0.005 & (0.009) \\
\hline
\multicolumn{2}{c}{Department-2 digit sector fixed effects} & \\
Adjusted $R^2$ & 0.023 & \\
Observations & 8750 & \\
\hline
\end{tabular}
\end{table}

Source: Authors’ calculations based on data from SUNAT and MTC. The upper panel of the table reports OLS of Eq. (2). The dependent variables are the change in the natural logarithm of export value, export quantity (weight), unit value, number of shipments, average exports per shipment, and average quantity (weight) per shipment at the firm-product-country level between 2003 and 2010. Exports consist exclusively of differentiated goods. Goods are classified as differentiated using the conservative version of the classification proposed by Rauch (1999). The main explanatory variable is a binary indicator that takes the value of one if the distance over which a firm shipped their products to their main port when exporting to a given country declined between 2003 and 2010 as a consequence of the new roads built in this period and zero otherwise. The lower panel of the table reports OLS estimates of a modified version of Eq. (2). The dependent variable is a binary indicator that takes the value of one if a firm exported in 2010 and zero otherwise. The main explanatory variable is a binary indicator that takes the value of one if the distance over which a firm could ship their products to their (potential) main port when exporting declined between 2003 and 2010 as a consequence of the new roads built in this period and zero otherwise. Initial and final routes are identified based on the ports used by exporting firms that belong to the same sector and are located in the same province. The estimating sample consists of all active firms belonging to tradable sectors that did not export in 2003. Department-2 digit HS sector fixed effects are included (but not reported). Standard errors clustered by department are reported in parentheses below the estimated coefficients. $^*$Significant at the 10% level; $^{**}$Significant at the 5% level; $^{***}$Significant at the 1% level.

\textsuperscript{45} The tests for overidentifying restrictions is a test of joint-exogeneity and, as such, do not strictly provide information on the validity of the instruments, but on their coherence, i.e., whether they identify the same vector of parameters (see Parente and Santos Silva, 2012).
\textsuperscript{46} This is the range of the resampling block sizes for which the test exhibits best size accuracy.
\textsuperscript{47} This estimated coefficient is larger than the ordinary least squares counterpart. The same results pattern holds in several related studies (see, e.g., Baum-Snow, 2007 and Duranton and Turner, 2012). Notice, however, that, in our case, a Hausman test indicates that ordinary least squares and instrumental variables estimates are not significantly different from each other.
\textsuperscript{48} A major concern with these instrumental variable estimates is that the exclusion restriction may not hold. Thus, it might be argued that regions or cities that were large and productive in the Inca times and got a better access to the road network are still today large and productive and, accordingly, tend to export more or that there are geographical factors that may be correlated with both the Inca road network and production and exports (see, e.g., Ramcharan, 2009). In this sense, note, first, that while there seems to be some relationship between relevant municipality-level variables such as population, population density, and the share of urban population and the Inca Roads variables, no association at all is observed in our sample after conditioning by region fixed effects as we do in our baseline estimations. Second, to further mitigate this concern, we re-estimate the alternative specifications of the export equation that include province or municipality fixed effects combined with sector fixed effects or firm(-region-sector) fixed effects with our instrumental variables procedures. Estimation results are presented in Columns 4–9 of Table 6 and corroborate those shown before. Third, the variables related to the Inca road network might be specifically better at predicting road constructions that are important for exports. Nevertheless, the estimated coefficient of the first-stage equation as estimated on the subsample of exporting municipalities does not significantly differ from the counterpart estimated on the subsample of never exporting municipalities. Finally, the road network in Peru consists of national and departmental roads, which have different purposes. Thus, national roads interconnect the country
longitudinally and transversely to allow for transport and commercial links with neighboring nations, connect the departments’ capitals with each other and the main production and consumption centers, and articulate national and international ports and airports as well as railways. The departmental roads link the departmental capitals with the provincial capitals, each of these capitals with each other, and municipalities in different provinces enabling the circulation of people and goods at the regional level, and articulate regional ports and airports (see MTC, 2005, 2010, 2011 and Zecerrano Mateus, 2011). Clearly, national roads play a more important, direct role for foreign trade. We therefore re-estimate Eq. (2) on a sample that excludes all observations with new national road segments. Also in this case, these estimates are in line with our benchmark ordinary least squares and instrumental variables estimations.53

In closing this subsection, we should stress that, even though our instrumental variables estimates appear to be seemingly convincing, they cannot be considered enough to establish causality by themselves because the exclusion restriction could be allegedly potentially violated even after including different sets of fixed effects.54

3.4. Channels and the extensive margin

Our data also allow us to explore the channels through which effects arise. In particular, we estimate the impact of new roads on the quantity (weight) shipped, the unit values, the number of shipments, and the average value and quantity per shipment, based on Eq. (2). Estimation results are presented in the upper panel of Table 7. These results reveal that expansion in transport infrastructure, by leading to decreased distances to ports and therewith to lower transport costs, has translated into larger shipments and thereby into increasing quantities shipped, but has not influenced unit values.

Up to this point, we have primarily focused on the export intensive margin (i.e., continuing flows). Increased transport infrastructure might have also helped some firms start exporting. Hence, we also examine the effect of changes in available roads on the firm export extensive margin by estimating a linear probability model paralleling Eq. (2) in which the dependent variable is a binary indicator that takes the value of one if the firm began to export in 2010 and zero otherwise on the sample of active firms belonging to tradable sectors that did not export in 2003.55 Estimation results are reported in the lower panel of Table 7. According to these results, road infrastructure innovations do not seem to have had a significant impact on firm entry into foreign markets.56 This is confirmed when we estimate Eq. (2) on data at the municipality-sector-product-destination level and use as a dependent variable the number of firms exporting a product to a destination in a given municipality-sector pair.57

3.5. General equilibrium effects

The positive effects of transport infrastructure on exports revealed by our estimations can originate from increases in firms’ foreign sales whose distance to the respective main port declined as a consequence of the roads built during our sample period without other firms’ foreign sales being affected. In this case, aggregate exports would have experienced a net expansion. However, such estimated effects could be also observed if these larger exports from firms getting new roads would be at the expense of those from counterparts that are not beneficiaries of the infrastructure projects. In the extreme scenario in which both compensate, a mere redistribution of exports across firms would have taken place and total exports would have not changed. Given their different implications for the economy as a whole, it is crucial for a proper evaluation of infrastructure investments to establish whether and to what extent they cause changes in the level of exports vis-a-vis a simple reallocation across economic units.

Assuming that the aforementioned externalities are restricted to the same municipality or the same province and are specific to foreign sales of given products (e.g., HS 4 digit products to allow potential substitutability across finely defined HS 6 digit goods belonging to a given HS 4 digit category), we do so by estimating our differenced Eq. (2) on alternative subsamples that involve comparisons between (1) exports with shorter routes to ports (“treated”) and their counterparts in the same municipality/province without changes in their roads exporting the same HS4 products (“untreated”); (2) “treated” exports and those from other municipalities or provinces without changes in their roads exporting other HS 4 digit products (“residual”); and (3) “untreated” and “residual” exports (see Redding and Turner, 2014). Alternatively, to avoid the arbitrariness implicit in administrative divisions, externalities can be assumed to be similarly localized but in terms of distance ranges (e.g., 100 or 300 km). Keeping in mind that these exercises critically depend on the assumptions regarding the nature of the spillovers and that they should accordingly be taken as indicative, we present the estimates of these equations in Table 8. Estimates point to no significant differences between “untreated” and “residual” both with each other and relative to “treated” export flows. This would suggest that improvements in domestic transport infrastructure seem to have had a net positive effect on country’s exports of differentiated products.

Moreover, better roads for some exports might have directly affected the survival of similar exports coming from nearby areas without improved transport infrastructure. In order to investigate whether such full crowding out took place, we estimate a linear probability model on the sample of firm-product-destinations flows existing in 2003 separately for “treated” and “untreated” observations and “treated” and “residual” observations, whereby the dependent variable is a binary indicator taking the value of one if the export flow is present in 2010 and zero otherwise and the explanatory variable is a binary indicator taking the value of one if exports could be shipped to the port along a shorter route thanks to the new roads built from 2003 to 2010 and zero otherwise, and region-sector fixed effects.58 In addition, survival of “untreated” and “residual” export flows could be compared by estimating a similar linear probability model but on the sample of firm-product-destinations flows existing in 2003 with no change in routes in subsequent years and using as the main explanatory variable a binary indicator that takes the value of one if there is at least an export flow with improved access to port within a given geographical unit or within a certain distance and zero otherwise (or their number). Again, there is no evidence that the infrastructure investment treatment has benefited some export flows at the price of

53 These estimation results are reported in Table A.15.1 in the online Appendix.
54 According to Eqs. (2) and (3), we are instrumenting changes in the road network with its initial level. In this Arellano–Bond type of estimation, a key identifying assumption is that the factors included. This condition may not hold in our case.
55 The main explanatory variable is, as before, the binary indicator of changes in available transport infrastructure. Initial and final routes of these non-exporting firms are primarily identified based on the main ports used by their exporting counterparts that are located in the same province and belong to the same sector.
56 In the same vein, it might be thought that increased firms’ exports thanks to infrastructure improvements may have favored the creation of other firms through backward linkages. Estimates of a similar equation in which the dependent variable is the change in the natural logarithm of the number of active firms in a municipality-sector pair over the sample period and zero otherwise do not provide support to this hypothesis (see Table A.16.1 in the online Appendix).
57 Table A.17.1 in the online Appendix reports estimates obtained using data at the municipality-sector-product-destination level.
58 Estimation results are similar if we instead include firm and product-destination fixed effects. These alternative estimation results are available from the authors upon request.
pushing others out of international markets.\footnote{See Table A.18.1 in the online Appendix.} We now turn to the effect of exports on employment.

4. From exports to employment

The previous section has established that improved domestic road infrastructure is associated with increased firms’ exports. In this section, we build upon these findings to explore to what extent these increased exports lead to employment growth.\footnote{Unfortunately, we do not have firm-level data on production or sales.} There are important challenges to identification of a causal relationship between these variables as several factors can affect firms’ employment. Despite these limitations, we believe that this byproduct analysis can provide interesting insights on the broader economic (non-strictly trade) implications of infrastructure investments as typically argued in national export plans.

In carrying out this analysis, we assume the following empirical model of employment:

\[
\ln L_{frs}(t) = \beta \ln X_{frs}(t) + \gamma_{frs} + \pi_{frs}(t) + \nu_{frs}(t) 
\]

(4)

where \( L \) corresponds to the firms’ number of employees and \( X \) to firms’ total export value. The remaining terms of Eq. (4) are control variables. Thus, \( \gamma_{frs} \) is primarily a set of firm fixed effects that captures, for instance, firm’s productivity and other firm-level factors that are constant over time; \( \pi_{frs}(t) \) is a set of region-sector-year fixed effects that controls for potential region-sector time varying factors such as
labor market frictions, labor participation rates, wage differential across region-sectors, and public policies (e.g., subsidies to SMEs) aimed at promoting employment in particular sectors in certain departments (see, e.g., [INEI, 2011]); and $v_{rs}(t)$ is the error term.  

As before, we first-differentiate Eq. (4) to eliminate the firm-region-sector fixed effects. Thus, we estimate the following baseline employment equation:

$$\Delta \ln L_{rs} = \beta \Delta \ln X_{rs} + \pi' + v'_{rs}$$

(5)

where the dependent variable is the annual average log change in the firms' number of employees: $\Delta \ln L_{rs} \equiv (\ln L_{rs}(2010) - \ln L_{rs}(2003))/7$; the main explanatory variable is the annual average log change in exports: $\Delta \ln X'_{rs} \equiv (\ln X_{rs}(2010) - \ln X_{rs}(2003))/7$; $\pi' = \alpha_0(2010) - \alpha_0(2003)$ absorbs all region-sector shocks; and $v'_{rs} = v_{rs}(2010) - v_{rs}(2003)$.

Clearly, exports can be endogenous to employment. Hence, we alternatively instrument them with the predicted values derived from our previous ordinary least squares or instrumental variables estimations of Eq. (2).  

61 Note that, after conditioning on region-sector fixed effects, these predicted values are primarily driven by the change in road infrastructure. Under the assumption that the change in infrastructure is exogenous either directly or once instrumented with the distance to and on the Inca Roads, the implied variation in exports can then be used to identify the impact of infrastructure-related exports on employment at the firm level.

More precisely, we first compute the predicted export values for each firm-product-country from Eq. (2) using the estimated coefficients reported in Tables 2 and 4. These predicted values can be summed over product-destinations to arrive at a prediction for the change in firm-level exports (see, e.g., Frankel and Romer, 1999; and Feyrer, 2009). Formally, we obtain a prediction for the total logarithmic export change for each firm as follows:

$$\Delta \ln X_{rs} = \hat{\alpha} + \sum_{f, p} \sum_{c} x_{fjpc}(2003) D_{jpc}(2010)$$

(6)

We then use the annual average predicted value as the instrument for actual annual average export change in estimating Eq. (5) by instrumental variables.  

62 Because the first-differenced firm-level employment equation includes region-sector fixed effects, the identification comes from the within region-section variation and, hence, is not generated by these effects.  

63 A possible concern with our specification is that our instrument does not satisfy the exclusion restriction. In order for this restriction to be fulfilled, we need that, after conditioning on region-sector fixed effects, infrastructure only affects employment through exports instead of directly via alternative mechanisms. An informal way to assess whether this is the case is to include the infrastructure improvement indicator $D$ as an additional separate explanatory variable. It turns out that the change in infrastructure has a non-significant and virtually null effect on employment growth (see Table 9). This suggests that most of the employment effect of the new roads is going specifically through exports as opposed to other channels (e.g., domestic trade, migration, etc.).

Table 9 reports ordinary least squares and instrumental variable estimates of Eq. (5) and variants thereof, also accompanied in this case by the first-stage results and the specification test corresponding to the latter for years 2003–2010. The $F$-test statistic as well as the under-identification test statistic indicate that our instruments are relevant. The estimated ordinary least squares coefficient indicates that increased exports are indeed associated with employment growth.

Importantly, the instrumental variable estimate reaffirms the conclusion we draw from the OLS estimate. In fact, these estimates are not statistically different from each other. These estimates specifically suggest that a 10% increase in the (rate of growth of) exports—driven by improved transport infrastructure—leads to a 3% increase in the (rate of growth of the) number of employees. This estimated elasticity is remarkably similar to that estimated in Park et al. (2010) on a sample of Chinese firms over the period 1995–2000 using exchange rate shocks as instruments for changes in exports.

As a robustness exercise, we re-estimate Eq. (5) using as an additional instrument the weighted average change in the GDP of exporting firms’ destination countries between 2003 and 2010 where the weights are the share of these countries in the firms’ total exports in the initial year.  

64 Results from this estimation are reported in Columns 4 to 6 of Table 9. These results are in line with those discussed above and, importantly, pass all specification tests.  

65 Note, however, that the same concerns regarding the possible violation of the exclusion restriction discussed when presenting the instrumental variables estimated impact of road infrastructure on exports, also apply here. In particular, either the new roads or the Inca roads can conceivably affect current firms’ employment through channels other firms’ foreign sales.

In closing and having these caveats in mind, we use the previous estimations along with the firm-level data at hand to provide some quantification of the export-related impact of road infrastructure on employment. First, firms-product-destinations that saw their distances to the main ports reduced have registered an average (logarithmic) export growth of 87.1% between 2003 and 2010. Based on the estimates of the export equation in long differences, 25.9% of this growth can be attributed to domestic transport infrastructure improvements. Long differences equivalents to estimates presented in Table 9 then imply that employment would have grown by 6% in the aforementioned companies as a consequence of the increased exports that the construction of the new roads allowed for. Further, given that the (logarithmic) growth of the total number of employees of these companies was 57% and that around 23% of this growth can be traced back to increased foreign sales, this would mean that infrastructure-driven exports accounts for approximately 4% of the (net) new jobs that were already available to sell in Peruvian main economic centers such as Lima, but those recently constructed also made it possible to sell more abroad. Unfortunately, data required to establish whether this has been actually the case are not available.
To sum up, our econometric results provide robust evidence that increased road infrastructure, by reducing the distance that shipments must be transported along to the respective main ports and hence the incurred transport costs, translated into larger firms’ exports and higher employment. Further, this deepened penetration of foreign markets seems to have in fact been associated with higher employment.

5. Concluding remarks

Public investments in transportation infrastructure are often justified by arguing that resulting new roads (or improved roads) would help firms expand their exports. Larger foreign sales would then lead to more jobs. However, whether and to what extent this presumption finds support in reality is virtually unknown. In this paper, we address this relevant policy question, thereby filling a notorious gap in the literature. We primarily examine the effects of new roads constructed in Peru between 2003 and 2010 on firms’ exports. In addition, we explore the subsequent impact on employment. In so doing, we exploit a rich dataset consisting of the universe of export transactions of differentiated goods in these years and detailed geo-referenced information on the road network. Also important, we address potential endogeneity of new road infrastructure by including extensive sets of fixed effects that control for a myriad of possible unobserved founders and, in robustness checks, by performing placebo tests and by resorting to an instrumental variables approach that uses the Inca Roads as instruments. Results consistently suggest that new roads have made possible increased firms’ exports. Further, this deepened penetration of foreign markets seems to have in fact been associated with higher employment.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jdeveco.2016.10.002.

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