From mine to coast: transport infrastructure and the direction of trade in developing countries

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July 13, 2012

Abstract

The transport infrastructure that developing countries have inherited from colonial times - and that persists nowadays - was primarily designed to facilitate the export of natural resources to overseas destinations. Consequently, such infrastructure specializes in the connection of resource-rich localities in the interior to the coast, and not so much in connecting neighboring localities or countries. To the extent that it can be used by other trades as well, such infrastructure may bias a country's structure of transport costs in favor of overseas trade, and to the detriment of local and regional trade. We investigate this potential bias in the direction of trade due to natural resource exports in the context of a gravity model of trade. Our main findings are that coastal countries that have more mines trade less than average with their neighbors, and that this effect is stronger when the mines are located in such as way that the transport infrastructure has a stronger potential for trade redirection. Consistently with the idea that this effect is due to transport infrastructure, landlocked countries that have more mines still trade less than average with their non-transit neighbor, but trade more then average with their transit neighbor. Furthermore, this effect is specific to mines and not to oil and gas fields, presumably because pipelines cannot be used by any other trade. We discuss the potential welfare implications of our results, and relate these to the debate on the long-run consequences of colonial economic policies for developing countries.

*Preliminary draft, please do not quote or circulate. Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank nor of the Eurosystem of central banks. We are grateful to Brian Kovak, Torfinn Harding, Pierre-Louis Vezina, Tony Venables, seminar participants at the University of Oxford and VU Amsterdam, the 2011 CSAE Conference in Oxford and the 2012 Rocky Mountain Empirical Trade Conference in Vancouver for helpful comments and suggestions.
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1 Introduction

There has been an increasing interest, in recent years, over the long-run consequences of colonial rule for developing countries. One argument that has received little attention by modern economists - but that was hugely influential in the past - holds colonial policies responsible for destroying local and regional trade in the colonies, to the benefit of trade between the colonies and the mother country. In the long-run, this led to an adverse pattern of specialization, whereby all high value-added activities are undertaken in faraway countries, and the former colonies are bound to be in a condition of *dependency* on their former colonial masters (e.g. Amin, 1972; Dos Santos, 1970). Key to this result, it is claimed, was the structure of colonial investment in transport infrastructure. Colonial rails and roads were constructed to connect the interior to the coast. This was intended to facilitate the exports of raw materials and the import of European manufactures, and had nothing to do with the exigencies of local and regional trade (e.g. Rodney, 1982, p. 209). By strengthening the comparative advantage of overseas manufactures, this contributed to displacing existing local and regional producers. This pattern of transport infrastructure persisted after decolonization, partly because new infrastructure commands high fixed costs and cooperation between countries, and partly because (with recently the help of China) they are still maintained mostly for natural resource exports.

A casual look at the structure of African colonial railways immediately suggests why these arguments may have gained considerable popularity. Figure 12 in the Appendix reports a map of African colonial railways in the 1930s, at the heyday of colonial power. As the map clearly shows, colonial railways mostly connected the interior of the African countries to the coast, while there were very only few links connecting neighboring African countries. Furthermore, many of these links appear to have been designed primarily to connect the interior of a landlocked country to the coast. This interior-to-coast pattern of African colonial railways emerges even more clearly from a larger map of West African railways in the 1960s, the years following independence (Figure 13). Strikingly, this pattern seems to have remained unaltered in the thirty years following independence. The map in Figure 14 describes the structure of African railways in the 1990s. Clearly, these appear to be remarkably similar to those described in the previous two figures.

While an interior-to-coast pattern of transport infrastructure does not, *per se*, imply that such infrastructure is sub-optimal, the suspect that it actually permeates in contemporary trade and development literature on Africa. For example, the trade literature has repeatedly documented the fact that intra-African trade is "too small", compared to what the gravity model of trade predicts and that much of it can be attributed to the poor quality of transport infrastructure (e.g. Limao and Venables, 2001). Also Sachs et al. (2004, p. 182) maintain that "Not only does sub-Saharan Africa have extremely low per capita densities of rail and road infrastructure, but indeed existing transport systems were largely designed under colonial rule to transport natural resources from the interior to the nearest port. As a result, cross-country transport connections within Africa tend to be extremely poor and are in urgent need of extension, to reduce intraregional transport costs and promote cross-border trade".

In this paper, we investigate empirically whether the little volumes of regional trade of developing countries may be attributed to their specialization in the export of natural resources, and the asymmetric effects on trade costs of the interior-to-coast pattern of transport infrastructure. In particular, we focus on the impact of *mine-to-coast* transport infrastructure. Drawing inspiration from some of the arguments of dependency theorists, we formulate and test the following hypothesis. International specialization implies that resource-rich developing countries tend to export most of their natural resources to developed countries. Because most developed countries are located in overseas continents from the perspective of developing countries, this will require the construction of transport infrastructure connecting the resource-producing regions of developing countries to the coast, and from there to overseas markets. Thus, we expect that countries with a larger number of active mines will have a larger and better stock of transport infrastructure (rail, roads, and ports) connecting its mines to the coast. To the extent that such transport infrastructure - originally designed to export mineral resources - can also be used to *import* a broad set of goods, we expect this to reduce the transport costs faced by the country to import from overseas countries. Thus, we expect that, on average, a larger number of active mines should imply a structure of transport costs that is more biased in favor of imports from overseas countries (as opposed to neighboring countries), thus explaining the above-described trade redirection effect of mines. While we would like to test directly whether or not the trade redirection effect of mines can be attributed to existence of mine-to-coast transport infrastructure, lack of data on the size, quality and direction of transport infrastructure for a sufficiently large number of countries prevents us from following that approach. We proxy infrastructure with the number and location of mines and follow a number of strategies to test our hypothesis indirectly. We proceed in five steps.

First, we estimate a gravity model of bilateral trade flows (controlling for importer and exporter fixed effects and a range of measures of trade costs), to show that countries with more mines import less than average from regional trading partners, here simply defined as countries with which the destination country shares a border. This qualifies the standard gravity result that neighboring countries trade more with each other and may eliminate it or even overturn it for countries that have a sufficiently larger number of mines. For example, the positive neighbor effect on trade disappears altogether for the 40 most important mining countries.

Second, if our hypothesis is correct, we expect that mines should have a stronger trade redirection effect in developing countries than in developed countries. This is because developed countries will tend to retain a larger part of their mineral resources for domestic or regional consumption. For these countries, a larger number of mines will then be less likely to result in a network of transport infrastructure that is biased in favor of overseas trade. To test for this prediction, we split our sample into OECD and non-OECD destinations, and estimate the trade-redirection effect of mines separately for these two sub-samples.

Third, we expect that, if our hypothesis is correct, the trade-redirection effect of mines should be stronger when the exogenous location of mines is such that they affect import trade costs more. For example, imagine a straight line connecting a mine to the closest point on the coast. If this line cuts through many cities, we expect the mine-to-coast transport infrastructure associated with this mine to have a large potential for trade redirection, since its presence will affect the transport costs faced by a large proportion of the country's population. We construct an index capturing the "trade-redirection potential" of a country's mines, and test for the prediction that the trade-redirection effect of mines is stronger in countries with a higher value of the index.

The fourth strategy derives from the existence of landlocked countries in our sample. Among landlocked countries, those that are resource-rich *and* developing will also tend to export most of their mineral resources to overseas countries. However for these countries, the mine-to-coast transport infrastructure will necessarily cut through at least one *transit* neighbor. If mine-to-coast transport infrastructure is what is driving the trade redirection effect, then such effect should disappear for imports from transit neighbors. This is because imports from transit countries benefit from the mine-to-coast transport infrastructure just as much as overseas countries do, if not more. We thus distinguish in our specification between normal neighbors and transit neighbors, and test for any difference in the trade-redirection effect between the two. Moreover, mines should only have a systematically different impact on imports from transit neighbors (relative to normal neighbors) in non-OECD countries, but not in OECD countries.

Finally, our last strategy is a falsification exercise based on the observation that, if mine-to-coast transport infrastructure is what is driving the trade redirection effect, this effect should disappear when we look at specific types of mineral resources that are unlikely to generate mine-to-coast infrastructure that can be used by other trades as well. We add to our main specification the number of oil and gas fields, on the premise that oil and gas, differently from other mineral resources, tends to be transported by pipelines.

We find compelling evidence in favor of our hypothesis. When we split the sample in OECD us non-OECD destinations, we find that the trade redirection effect disappear for the first group of countries, while it is still there for the second group of countries. This result is robust across the various specifications of our regressions. For a given number of mines in the destination country, we find that, in our core sample of non-OECD destinations, the trade redirection effect is larger when the index measuring the trade redirection potential of the country's mines is high. In other words, the exogenous location of mines has an independent effect on the direction of national trade, and this is consistent with the effects of mine-to-coast transport infrastructure associated with those mines. While this effect is non significant for non-OECD destinations, it is highly significant in a subset of all African destinations. As expected, we find that landlocked destination countries import with a larger number of mines import less the average from their normal neighbors, but not from their transit neighbors. In fact, the trade redirection effect becomes positive for this latter group of neighbors. Furthermore, we do find that mines do not have any systematically different impact on imports from transit neighbors (relative to normal neighbors) in non-OECD countries, but not in OECD countries. Finally, our falsification exercise yields the desired result: there is no trade redirection effect associated with neither the number nor the location of oil and gas fields, and this results extends to all of our subsamples.

These results are consistent with the idea that specialization in the export of natural resources has, through transport infrastructure, a re-direction effect on the trade of developing countries. One must be very careful in drawing quick welfare implications from this, however. For one thing, while the interior-to-port transport infrastructure will be biased in favor of imports from overseas countries, it will still be associated with an overall decrease in national transport costs. Since this will have positive welfare implications for domestic consumers and producers, we cannot draw any clear welfare implications for the citizens of the country where this transport infrastructure is built. Furthermore, we cannot conclude that developing countries with more mines trade less from neighbors *in absolute terms*. This is because all of our specifications include importer fixed effects, which will absorb any positive (or negative) effect that the mines have on national trade.

We believe our results allow us to make some interesting conjectures on possible welfare implications. The interior-to-coast transport infrastructure is likely to have a negative welfare effect on local and regional industries that compete with imports from overseas countries. For these industries, the interior-to-coast transport infrastructure may entail a substantial reduction in market access, which may lead to severe efficiency losses (e.g. Collier and Venables, 2010). More in general, the segmentation of regional markets may lead to a suboptimal size of regional centers of production (e.g. cities), and thus to an overall fall in productivity (*Ibid.*). Such small market effects are often thought to be consequential for the capacity of developing countries to achieve economic growth (e.g. Sachs et al., 2004, p. 131). Clearly, we expect these effects to be particularly negative for regional trading partners, since these countries do not benefit from a direct reduction in the reduction in transport costs associated with mine-related infrastructure.

The paper is organized as follows. The next section discusses the related liteature, after which we construct a simple gravity model that illustrates our idea and derives our hypothesis in section 3. After describing the data in section 4, we test our hypothesis in section 5, and conduct some robustness checks in section 6. We then use section 7 and 8 to discuss our finding and to comment on welfare implications, and section 9 to conclude.

2 Related literature

Our paper relates to the dependency school, which held that integration in the world economy has put developing countries in a position of dependency, whereby, by specializing in the export of primary products and becoming dependent on the world economy for imports of all other products, they fall in a condition of underdevelopment. This process was facilitated by the colonial and neo-colonial relation that these countries entertained with some of the key players in the world economy. This thesis took its origins in the famous work on developing countries' terms of trade by Prebisch and Singer, and became very influential in the 1960s and 1970s as an antithesis to modernization theories.[1] The argument that transport infrastructure played a key role in all this has been made, among others, by Rodney (1982, p. 209), and Freund (1998, p. 99). For example, Rodney states that "The combination of being oppressed, being exploited, and being disregarded is best illustrated by the pattern of the economic infrastructure of African colonies: notably, their roads and railways. These had a clear geographical distribution according to the extent to which particular regions needed to be opened up to import-export activities. [...] There were no roads connecting different colonies and different parts of the same colony in a manner that made sense with regard to Africa's needs and development. All roads and railways led down to the sea. They were built to extract gold or manganese or coffee or cotton. They were built to make business possible for the timber companies trading companies, and agricultural concessions firms, and for white settlers. Any catering to African interests was purely coincidental."

The literature on the pattern of intra-African trade has investigated the openness of the African countries among each other, relative to the standard provided by the gravity equation. Limao and Venables (2001) find that trade between pairs of SSA countries is significantly lower than trade between pairs of non SSA countries, even after controlling for income, per capita income, neighbors and other standard geographical variables such as distance and an island dummy. However after controlling for a rough measure of national infrastructure,[2] this difference

[1] See Dos Santos (1970) and Amin (1972) for a concise enunciation of the theory.

[2] The authors use Canning (1998)'s index of road, paved road and railway densities and telephone lines per capita.

becomes significantly positive. They also find that the negative effect of distance on bilateral trade flows is larger for SSA than for non-SSA pairs. Similar results are found in Longo and Sekkat (2001), who also control for other possible determinants of little intra-African trade such as poor economic policy and political tensions.

In our mechanism, the need to export natural resources leads to a biased structure of transport costs in developing countries, which favors trade with overseas trading partners to the detriment of trade with regional trading partners. Because a fall in transport costs has a similar effect on trade patterns as a fall in tariffs, our mechanism is conceptually related to the literature on North-South us South-South trade agreements (or custom unions). Such literature has sought to understand whether the interests of developing countries in the South are better served by trade agreements with developed countries in the North, or with neighboring developing countries. For example, Venables (2003) finds that for a medium-income developing country, to sign a custom union with developed countries may be less welfare enhancing than to sign it with a low-income neighbor, while for the latter the opposite is likely to be true.

The literature on the resource curse (see van der Ploeg, 2011, for a recent survey) has presented various arguments why natural resource booms may not be a great source of domestic growth for developing countries. Our results suggest that they may not be a great source of growth for regional trading partners either, if they are accompanied by an infrastructure-driven re-orientation of trade towards overseas countries. Because of these implications, the paper is related to the literature on international growth spillovers (e.g. Easterly and Levine, 1998; Roberts and Deichman, 2009), and particularly those papers that look at natural resource booms explicitly (e.g. Venables, 2009).

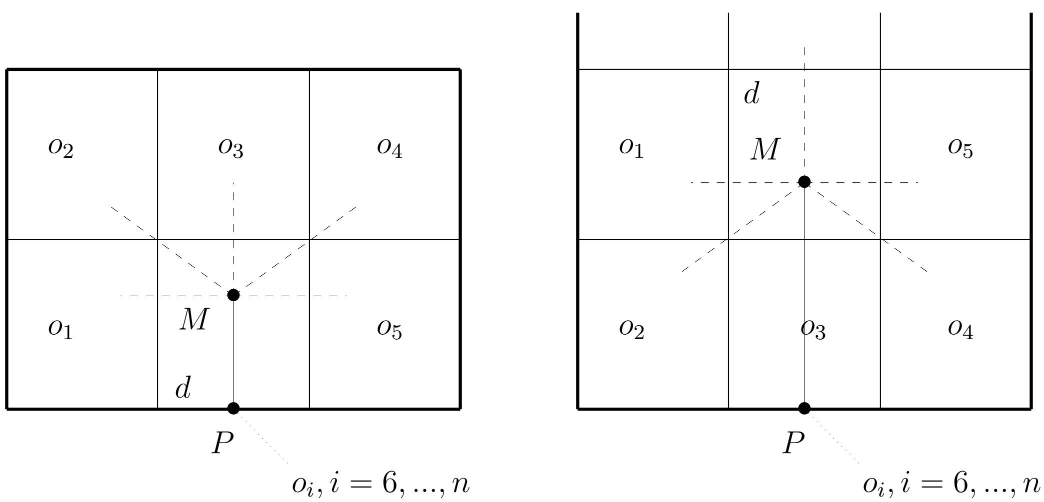
3 Model

We begin from a standard gravity equation specifying the expected imports of country d ("destination") from country o ("origin"):

$$\ln \mathrm{imp}_{od} = k - \ln \widetilde{\tau}_{od} + a_o + a_d + v_{od},$$

where $\widetilde{\tau}_{od}$ is an index capturing all the costs incurred to import goods from o to d, a_o and a_d are origin and destination fixed effects, and v_{od} is a random error.

Consider first a world with only coastal countries. A stylized image of such a world is represented in Figure 1, Panel I, which represents a destination country and n origin countries (o_i), both on the same continent ($i = 1, ..., 5$) and overseas ($i = 6, ..., n$). The existence of mines in the destination country will normally be associated with the existence of mine-related transport infrastructure, connecting the mines to foreign markets. In the figure, the potential location of such infrastructure is represented by the solid and dashed lines that connect point M to foreign markets. At least in some cases, the mine-related transport infrastructure will be usable by other trades as well, thus reducing d's cost of importing from the various o_i. The question then arises, will this effect of transport infrastructure favor imports from the various o_i in a roughly similar manner, or will it be systematically biased in favor of imports from some specific o_i?



Panel I: coastal d Panel II: landlocked d

Figure 1: Mine-related transport infrastructure, coastal and landlocked destination

Because developing countries tend to export their natural resources mostly to overseas, industrialized countries, we expect the mine-related transport infrastructure to be more likely to connect the mines to a port - from where the natural resources can be shipped to overseas markets - rather than to an overland border point with neighboring countries. In Figure 1, this is represented by the solid line connecting point M to point P - and from there to overseas markets. To the extent that d's imports from neighbors are less likely to be routed through P than are imports from non-neighbors, one hypothesis that we may then put forward is that the mine-related transport infrastructure will be less likely to reduce transport costs on import *from neighbors*, than on imports from non-neighbors. In the stylized world of Figure 1, such infrastructure will be less likely to reduce transport costs on imports from o_i with $i = 1, ..., 5$, than on imports from o_i with $i = 6, ..., n$.

Denote by $\phi^{\not{N}}$ the probability that the mine-related infrastructure reduces transport costs on imports from non-neighbors, and by ϕ^{N} the probability that it reduces them on imports from neighbors (with residual probability, the mine-related infrastructure has *no* effect on transport costs). We then expect $\phi^{\not{N}} > \phi^{N}$. Next, suppose that we are able to construct an index measuring the extent to which the transport infrastructure connecting the mines *to the port* is also usable by traders importing along that route. Denote such index by $\alpha_d \in [0, 1]$ (defined in Section 3.1), which is higher the more likely it is that the infrastructure is usable. We then hypothesize that the cost of importing from o to d is determined as follows:

$$\ln \widetilde{\tau}_{od} = \ln \tau_{od} - N_{od}\phi^{N}\gamma M_d - \left(1 - N_{od}\right)\phi^{\not{N}}\gamma\left(1 + \alpha_d\right)M_d - \delta N_{od},$$

where N_{od} is a neighbor dummy, γ is a parameter that measures the average effect of mine-related transport infrastructure on the cost of importing along that same route (we expect $\gamma > 0$), M_d is defined as $\ln(1 + m_d)$, where m_d is the number of active mines in d, and δ is a parameter that allows for the fact that transport costs may be lower between neighboring countries (we expect $\delta > 0$) for reason that have nothing to do with mine-related infrastructure. The term τ_{od} is then implicitly defined as the cost of importing from o to d, when d has no mines and the two countries are not neighbors. The second and third terms in the above expressions capture the expected effect of mines as discussed above.

Next, consider a world in which there are also landlocked countries, and consider the impact of mine-related transport infrastructure on a landlocked destination country. This case is represented in Panel II of Figure 1. As for the case of a coastal destination country, we expect that the mine-related transport infrastructure will be more likely to be *aimed* at connecting the mines to a port, as opposed to just any overland border point. For a landlocked destination country, however, a port can only be reached by first passing through an overland border, namely the one that connects the landlocked country to its *transit* neighboring country - the country where the port is located. In terms of Figure 1, the solid line between point M and P must pass through o_3, which is d's transit country. It follows that, if we consider the *non-transit* neighboring countries of our landlocked country (o_1, o_2, o_4 and o_5), the mine-related transport infrastructure will still reduce transport costs on imports from these countries less than on imports from other countries $(o_i, i > 6)$. However there will now be *one* neighboring country, the transit neighboring country (o_3) for which the mine-related infrastructure will reduce transport costs as well.

To account for the existence of landlocked destination countries, we modify the last expression for transport costs as follows:

$$
\begin{aligned}
\ln \widetilde{\tau}_{od} = \ln \tau_{od} - N_{od}\phi^{N}\gamma M_d - (1 - N_{od})\,\phi^{\not N}\gamma\,(1+\alpha_d)\,M_d - \delta N_{od} \\
- N_{od}T_{od}L_d\gamma\left(\phi^{\not N} - \phi^{N}\right)M_d - N_{od}T_{od}L_d\gamma\phi^{\not N}\alpha_d M_d - \zeta T_{od},
\end{aligned}
$$

where T_{od} is a dummy that takes value 1 if and only if o and d are in a transit relation, L_d is a landlocked dummy for the destination country, and ζ is a parameter that captures the fact that transport costs may be lower between countries in a transit relation (we expect $\zeta > 0$), for reason that have nothing to do with mine-related infrastructure.

To interpret the above equation, it is convenient to set $N_{od} = 1$, and consider how the second row modifies the expression for those neighboring countries that are also in a transit relation. Suppose d is landlocked and o is its transit country ($L_d = 1$, $T_{od} = 1$). The first term in the second row then allows for the fact that d's stock of mines has a higher probability to reduce transport costs from o, than from its other, non-transit neighbors. As for the second term in the second row, this reflects the fact that the impact of d's stock of mines on imports from o also depends on the index α_d, while that on imports from non-transit neighbors does not.

Re-arranging the first row of the above equation we obtain:

$$
\begin{aligned}
\ln \widetilde{\tau}_{od} = {} & \ln \tau_{od} - \phi^{\not{N}} \gamma \left(1 + \alpha_d\right) M_d + \\
& + \left(\phi^{\not{N}} - \phi^{N}\right) \gamma M_d N_{od} + \phi^{\not{N}} \gamma M_d N_{od} \alpha_d - \delta N_{od} - \\
& - N_{od} T_{od} L_d \left(\phi^{\not{N}} - \phi^{N}\right) \gamma M_d - N_{od} T_{od} L_d \gamma \phi^{\not{N}} \alpha_d M_d - \zeta N_{od} T_{od}
\end{aligned}
\tag{1}
$$

Having constructed an expression for the expected impact of mines on transport costs, we can plug this back into our gravity equation. Because the term $\phi^{\not{N}} \gamma \left(1 + \alpha_d\right) M_d$ is a characteristic of the destination country only, we can include that in d's fixed effect. The gravity equation then becomes:

$$
\begin{aligned}
\ln \mathrm{imp}_{od} = {} & k - \ln \tau_{od} + a_o + a_d + \\
& + \beta_1 N_{od} M_d + \beta_2 N_{od} M_d \alpha_d + \beta_3 N_{od} + \\
& + \beta_4 N_{od} T_{od} L_d M_d + \beta_5 N_{od} T_{od} L_d M_d \alpha_d + \beta_6 N_{od} T_{od} + \upsilon_{od},
\end{aligned}
\tag{2}
$$

where $\beta_1 \equiv -\left(\phi^{\not{N}} - \phi^{N}\right)\gamma$, $\beta_2 \equiv -\phi^{\not{N}}\gamma$, $\beta_3 \equiv \delta$, $\beta_4 \equiv (\phi^{\not{N}} - \phi^{N})\gamma$, $\beta_5 = \phi^{\not{N}}\gamma$, $\beta_6 = \zeta$.

Equation (2) is our main theoretical equation. The variables contained in the first row of equation (2), as well as N_{od} and T_{od}, contain standard gravity variables, and we expect $\beta_3, \beta_6 > 0$: neighbors trade more with each other, and that effect is even stronger for those neighbors that are also in a transit relation. Our coefficient of interests are β_1, β_2, β_4, β_5.

Summarizing, we expect $\beta_1 < 0$. This is because this coefficient is expected to capture the lower probability with which mine-related transport infrastructure favors trade with neighbors, as opposed to trade with non-neighbors. Because the index α_d measures the extent to which the infrastructure that could, *in principle*, favor trade with non-neighbors, is *actually* useful to this purpose, we also expect $\beta_2 < 0$: in words, for countries where α_d is high, not only there is a lower probability that mine-related transport infrastructure favors trade with neighbors It is also the case that such infrastructure is particularly useful to trade with non-neighbors, thus accentuating the difference between these two groups of countries.

While we expect mine-related transport infrastructure in d to favor imports from neighboring origins less than imports from non-neighboring origins, this should not be the case in a specific situation: when d is landlocked, and o is its transit country. In this case, we actually expect the mine related infrastructure to have the same effect on imports from o, as it has on imports from non-neighbors. For this reasons we expect $\beta_4, \beta_5 > 0$: essentially, these coefficients should "correct", for the case of transit neighbors, the negative relative impact that mines have on trade with non-neighbors.

3.1 Mine impact index

Next, we construct the index α_d measuring the extent to which the transport infrastructure connecting the mines to the port is also usable by traders importing along that route. Our approach is to consider how the geographical position of mines compares to that of *cities*, and how the ideal position of a port intended for the exports of mines' products compares to that of the country's main *container* port that is used for imports. Our index will then provide an estimate of the probability that the mine-related transport infrastructure overlaps - and thus, improves - the transport infrastructure connecting the cities to the country's main container port.

Consider a generic destination country. Denote by C the geographical center point of cities, by M that of mines, by P the country's main container port. Imagine to draw a line connecting C to P, and the perpendicular dropping from M to this line. Call I the point where the two lines intersect.[3] Finally, call S the closest coastal point to M. Then, our proposed index is:

$$\alpha_d = 0 \text{ if } \pi_d \text{ below average} \tag{3}$$

$$\alpha_d = 1 \text{ if } \pi_d \text{ above average} \tag{4}$$

where:

$$\pi_d = \Pr\{\text{mines use P}\} * \Pr\{\text{mines use CP}\} * \text{share of CP used by mines} \tag{5}$$

[3] Notice that I may well not lie between C and P; this case is further discussed below.

and where:

$$\Pr\{\text{mines use P}\} = \begin{cases} \frac{MS+1}{MP+1} & \text{if} \quad MS < MP \\ 1 & \text{if} \quad MS > MP \end{cases} \tag{6}$$

$$\Pr\{\text{mines use CP}\} = \begin{cases} \frac{MP+1}{MI+IP+1} & \text{if} \quad IP < CP \\ \frac{MP+1}{MC+CP+1} & \text{if} \quad IP > CP \end{cases} \tag{7}$$

$$\text{share of CP used by mines} = \begin{cases} \frac{IP+1}{CP+1} & \text{if} \quad IP < CP \\ 1 & \text{if} \quad IP > CP. \end{cases} \tag{8}$$

Equation (5) suggests that the index π_d is the product of three distinct terms. We will comment on these in turn. The first term is the probability that the mines use P to ship the resources they produce. Because P is the country's main container port, it is logical to expect that a large proportion of the country's imports from overseas will be shipped through this port. Thus, a logical prerequisite for the mine-related infrastructure to be shared by these imports seems to be that such infrastructure converges to port P. We proxy for the probability that happens through the expression in equation (6), whose logic is explained in Figure 2. Essentially, mine-owners face a choice between shipping the resources through port P, or establishing an *ad-hoc* port for the export of bulk commodities somewhere else along the country's coast. We assume that the optimal point to establish such an alternative port is on the closest coastal point to M, that is S. Mine-owners only base their choice on the relative distance of points P and S. Equation (6) captures the outcome of this choice: the smaller is the distance MP relative to the distance MS, the higher is the probability that mine-owners choose P instead of S. Such probability is defined between 0 and 1. In particular, if $M = S$ (that is, M is on the coast) and P is (infinitely) far, mine-owners always use S. If $P = S$ (that is, if P happens to be the closest coastal point to M), mine-owners always use P.

The second term in equation (5) captures the fact that, for a given probability that the mines use P to ship their resources, the relevance of mine-related infrastructure for overseas imports can be expected to be higher, the higher is the probability that the mines use CP as a route to carry the resource to P. This is because when this probability is high, the mine-related transport infrastructure is particularly likely to improve the connection between the port where imports from overseas are landed, and the cities which are such imports' their main domestic markets.

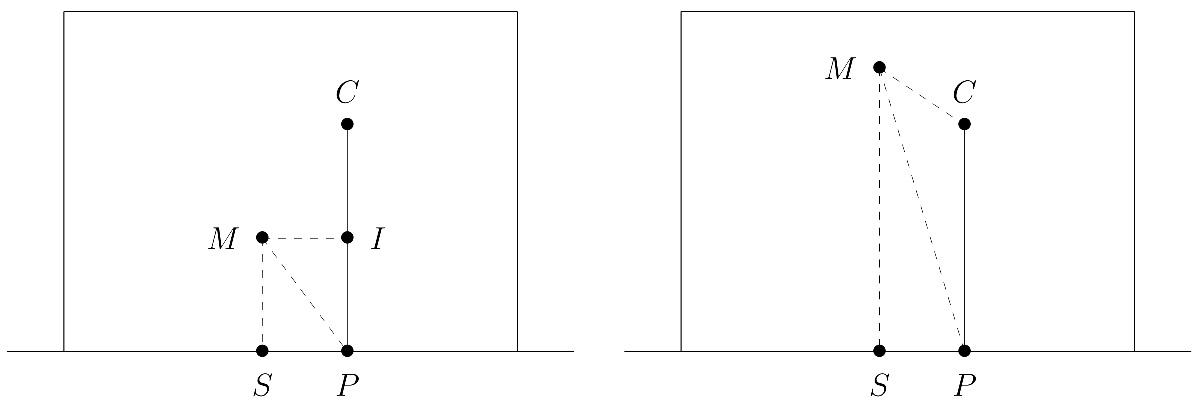
We proxy for the probability that the mines use CP as a route to carry the resource to P by the expression in equation (7), whose logic is also explained in Figure 2. Having decided to ship the resources through P, mine-owners face the choice of whether to carry their resources through P using the connection CP, or establish a direct connection. As for the choice between P and S, mine-owners only base their choice on the relative distance of P, when using the connection CP and when establishing a direct connection. However to determine the former distance we now need to distinguish two cases. On one hand, when $IP < CP$, point I lies between C and P. In this case, we take as the distance of P the sum of the segments MI and IP. The first row of equation (7) captures the outcome of the mine-owners' choice in this case. The smaller is $MI + IP$ relative to MP (the length the direct connection to P), the higher is the probability that mine-owners carry the resources to P using the connection CP. Differently from before, such probability is defined between $\frac{\sqrt{2}*IP+1}{2*IP+1}$ and 1. If $MI = IP$, mine-owners use CP with probability $\frac{\sqrt{2}*IP+1}{2*IP+1}$. If $MI = 0$ (that is, if M lies on the CP connection), mine-owners always use CP. On the other hand, when $IP > CP$, point I lies above C.[4] In this case, we take as the distance from M to P the sum of the segments MC and CP. This outcome of mine-owners' choice is then captured in the expression in the second row of equation (7), which is similarly defined between $\frac{\sqrt{2}*IP+1}{2*IP+1}$ and 1.

Thirdly, for a given probability that the mines use P through CP to export their resources, the expression in equation (8) captures the extent to which the mine-related infrastructure is likely to improve the connection between C and P. Here, we want to recognize the fact that mine-related infrastructure only overlaps with the connection CP over its portion closest to the port, that is IP. We thus assume that the impact of the mine-related infrastructure on transport costs between C and P is directly proportional to the share CP represented by IP. Once again, we need to distinguish between two cases, depending on whether point I lies below or above M (first and second row of equation 8). While in the former case the share of CP used by the mines

[4] This case is very relevant empirically, see for example the case of Cameroon, Cote d'Ivoire and the DRC in Figure 13.

ranges between 0 and 1 depending on how "high" is I, in the latter case the share is always 1. This is, of course, because we have assumed that the route used by the resources to reach P is through point C itself, so that the mine-related infrastructure overlaps with the entire CP connection.

Finally, we have collapsed the index π_d into a dummy indicator α_d. Although it is possible to work with π_d directly, we found that this did not lead to meaningful results. This probably means that our approximation is not accurate enough. However, without other priors on how to measure the true impact of the location of mines on city-port infrastructure, we choose to split the sample into two groups: those with a 'high' score, and those with a 'low' score of π. It is unlikely that these two groups would change composition much by choosing a different definition of π. For example, we indeed find that the results based on the indicator are robust to using different metrics of point C.

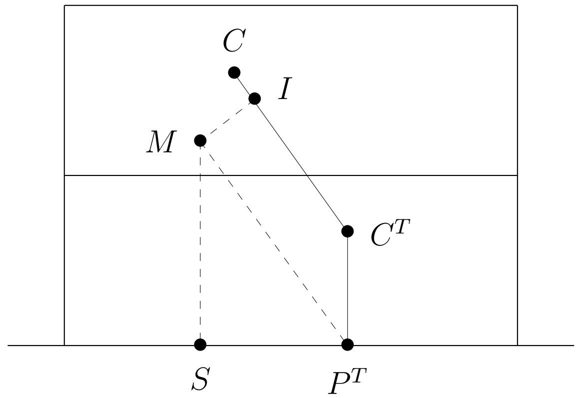


Panel I: $IP < CP$ Panel II: $IP > CP$

Figure 2: Construction of the mine impact index, coastal countries

We conclude by considering the case of landlocked countries as illustrated in Figure 3. Denote by C^T the geographical center point of cities in the transit country, and with P^T that country's main container port. Then, we construct the index just as indicated in (5), except that we substitute P with P^T and CP with CC^TP^T.[5] The latter is a hypothetical line connecting C to P through C^T.

[5]Notice that in many cases (e.g. Congo, the DRC, Kazakhstan, Zambia) point S may be in a third country.



Panel I: $IP < CP$

Figure 3: Construction of the mine impact index, landlocked countries

4 Data

To estimate the effect of infrastructure on trade we need bilateral trade flows between as many countries as possible and a measure of infrastructure. For trade, we rely on the UN Comtrade database which reports all known bilateral trade flows between countries in the world based on the nationality of the buyer and seller. We measure the value of trade at the importing country and we use the 2006 cross-section, which should cover more countries due to globalization and be of better quality than historical data, which is especially important for African data.[6] Even for this recent year, we find that out of 49,506 (223 by 223-1) possible trade flows only 57% are positive, while the other observations are coded as missing in Comtrade. Within Africa, there are 55 by 54 possible trade flows, and in 2006 we observe 60% positive flows. No trade flows are missing between OECD countries. Our typical regression will be able to include around 24,000 observations.

The main explanatory variable of interest is a measure of infrastructure, where we need to take into account not only the length of the road and rail network, but also its quality and direction. Although data exists on the total length of the paved road and rail network in many countries, we cannot observe the direction and quality of infrastructure directly. We will therefore use the number of mines as a proxy for the amount, quality, and direction of infrastructure that

[6]SITC Rev. 2, downloaded on Oct 30th, 2009.

Table 1: Imports as a share of total imports

destination:	origin:	mean	sd	min	max
OECD	neighbors	29%	20%	0%	74%
non-OECD	neighbors	16%	21%	0%	90%
Africa	neighbors	14%	22%	0%	89%
non-Africa	neighbors	19%	21%	0%	90%
non-Africa, non-OECD	neighbors	17%	20%	0%	90%
Africa	Africa, non-neighbors	11%	12%	0%	57%
World	neighbors	18%	21%	0%	90%

Means are means across countries within the given sample for bilateral trade volumes in dollars. Missing and zero bilateral trade flows are treated as zero. I.e., 29% implies that the average OECD country imports a volume of its known import flows from neighboring countries that represents 29% of all of its known imports. The OECD mean is significantly higher than all other means. The mean of the share of imports by African countries from non-neighboring African countries is significantly lower than all other means except the mean of the share of imports by African countries from neighbors. The other means are not significantly different at 95% confidence.

is related to the mining industry. Our hypothesis is that mining infrastructure is predominantly from the mine to the nearest port, such that it can be shipped to world markets. Countries with a larger number of active mines should therefore have more and better infrastructure towards the nearest port as opposed to population centers and neighboring countries.

A comprehensive source of data on the location of mines across the world is available from the US Geological Survey's Mineral Resources Data System (MRDS).[7] MRDS registers the location in geographic coordinates of metallic and nonmetallic mineral resources throughout the world. It was intended for use as reference material supporting mineral resource and environmental assessments on local to regional scale worldwide. Available series are deposit name, location, commodity, deposit description, development status, geologic characteristics, production, reserves, resources, year of discovery, year of first production, and references, although many entries contain missing values. The database is unfortunately focused on the geological setting of mineral deposits rather than on production and reserve information. The full database

[7]Edition 20090205. Source: http://tin.er.usgs.gov/mrds/

contains 305,832 records, but after extensive cleaning we are left with 20,900 mines.[8][9]

Within this selection of mines 66% are located in the US. The remaining 7122 mines cover 129 countries.

Table 2 reports the top 40 countries according to the number of mines in combination with the mine impact index. The US is clearly over-represented while China for example is probably under-represented. The table also shows that there is little correlation between the number of mines, and the degree to which these are likely to improve the infrastructure between major cities and ports. For example, Canada has many mines but these are too remote to affect infrastructure corridors much. In Chile the mines are so far from cities that they are most likely to have dedicated ports which cannot easily be used for imports by cities. In contrast, Guatemala has much fewer mines, but these are quite close to infrastructure between cities and ports. The average value for the index π_d is 0.46. We therefor categorize countries with $\pi_d > 0.46$ as those where city-port corridors are affected by mining, $\alpha_d = 1$ (such as South Africa), and those with $\pi_d < 0.46$ as those where city-port corridors are not affected by mining, $\alpha_d = 0$ (such as France).

Table 3 shows for major groups of countries summary statistics on the number of mines and the index value. Landlocked countries, from which the shipping costs to export resources are much higher, tend to have fewer mines, but the mines in these countries tend to affect infrastructure more (although this is less clear when we collapse the index into a dummy). The table also shows that Africa does not have so many mines even though many African countries depend on natural resource production. However, the index value is high in Africa suggesting that mines have a large influence on the transport costs between ports and cities.

Table 4 shows the top commodities according to what a mine reports as its main product. It shows that gold mines are most common. The top commodities also include heavy ores such as

[8] We drop the following records: OPER TYPE is processing plant or offshore; PROD SIZE is missing, small, none or undetermined; WORK TYPE is water or unknown; YR LST PRD was before 1960; DEV STAT is prospect, plant, occurrence, or unknown; SITE NAME is unnamed or unknown; and mines for which the coordinates fall outside its country's mainland.

[9] We have also investigated an alternative source. The private company Raw Materials Group also provides a database with metallic and nonmetallic mineral resources covering the world. The data has better, but incomplete, information on the mine status in different years. However, within this database we observe at least one mine in 96 countries, versus 133 countries in the MRDS data. This means that the RMG data excludes mines in three OECD counries, 11 African countries and a further 23 non-OECD countries, among which for example Mozambique and Senegal are know to be significant current producers of respectively aluminium and phosphates.

Table 2: Top mining countries and mine impact index

Country	Mines	π_d	Country	Mines	π_d
United States	14090	0.29	China	93	0.56
Mexico	713	0.30	Panama	85	0.82
Brazil	610	0.79	South Korea	84	0.57
Peru	528	0.66	India	80	0.41
Argentina	416	0.60	France	75	0.38
Canada	358	0.13	Philippines	57	0.05
Guyana	344	0.55	Guatemala	54	0.96
Colombia	337	0.34	Honduras	51	0.31
Russia	314	0.27	Zimbabwe	50	0.46
Australia	303	0.18	Spain	46	0.56
Venezuela	254	0.35	Dominican R.	40	0.59
South Africa	241	0.75	Turkey	37	0.52
Uruguay	209	0.88	Laos	35	0.31
Jamaica	165	0.51	Egypt	35	0.14
Bolivia	161	0.08	Thailand	35	0.40
Chile	159	0.06	Italy	35	0.05
Japan	129	0.07	Sweden	35	0.06
Cuba	129	0.09	Finland	32	0.36
New Zealand	118	0.00	Germany	31	0.77
Ecuador	108	0.79	Papua NG	26	0.14

Note: π_d is an index capturing the extend to which mines may improve infrastructure between cities and ports.

copper and iron which are usually transported by rail. Note also that the database excludes oil and gas.

We always control for a broad set of multilateral resistance terms taken from Head et al. (2010). These are *ln distance*, the log of distance between country centroids; *Shared language*, a dummy equal to one if both countries share a language; *Shared legal*, a dummy equal to one if both countries share the same legal origin; *ColHist*, a dummy equal to one if both trading partners were once or are still (as of 2006) in a colonial relationship; *RTA*, a dummy equal to one if both trading partners belong to a regional trade agreement; *Both WTO*, a dummy equal to one if both are members of the WTO; *Shared currency*, a dummy equal to one if they share a currency; and *ACP*, which is a dummy equal to one for trade between EC/EU countries

Table 3: Summary stats

Region	Mean M_d	Mean π_d	Mean α_d
Non-landlocked			
World	118.73	0.45	0.53
World ex-US	38.90	0.45	0.54
OECD	672.38	0.34	0.35
non-OECD	31.31	0.48	0.58
Africa	10.56	0.64	0.88
Landlocked			
World	9.05	0.50	0.50
World ex-US	9.05	0.50	0.50
OECD	2.5	0.46	0.75
non-OECD	10.32	0.51	0.45
Africa	5.67	0.56	0.50

Note: M_d equals the log of the number of mines in each country plus one; π_d is an index capturing the extend to which mines may improve infrastructure between cities and ports; α_d is a dummy equal to 1 if π_d is larger than its average of 0.46.

and members of the 'Asia−Caribbean−Pacific' preferential tariff agreement for former European colonies.

4.1 Measuring the mine impact index

To construct the mine impact index we need to find the the midpoint of mines in each country (M), the urban population weighted midpoint of main cities (C), the location of the main port (P), and the point on the shoreline nearest to point M (S). For point M we rely on the coordinates of all the mines in the country and calculate the geographic midpoint on the globe (where I_j is

Table 4: Top mining products

Total sample			Non-US sample		
Commodity	mines	%	Commodity	mines	%
Gold	3,057	14.71	Gold	1,026	14.54
Sand and Gravel	2,774	13.34	Sand and Gravel	368	5.22
Stone	2,060	9.91	Copper	300	4.25
Iron	741	3.56	Diamond	270	3.83
Uranium	529	2.54	Platinum	235	3.33
Gold, Silver	492	2.37	Gold, Silver	210	2.98
Copper	471	2.27	Iron	200	2.83
Stone, Crushed/Broken	402	1.93	Aluminum	198	2.81
Limestone, General	385	1.85	Manganese	178	2.52
Clay	302	1.45	Limestone, General	162	2.3
Chromium	280	1.35	Phosphorus-Phosphates	127	1.8
Diamond	270	1.3	Chromium	124	1.76
Uranium, Vanadium	268	1.29	Tin	123	1.74
Manganese	255	1.23	Tungsten	108	1.53
Tungsten	249	1.2	Fluorine-Fluorite	103	1.46
Phosphorus-Phosphates	248	1.19	Lead, Zinc	79	1.12
Platinum	239	1.15	Graphite	73	1.03
Fluorine-Fluorite	216	1.04	Mica	73	1.03
Aluminum	213	1.02	Kaolin	70	0.99
Stone, Dimension	208	1	Stone	69	0.98

the total number of mines i with WGS 84 coordinates $(latitude_i, longitude_i)$ in country j) as:

$$x_j = \sum_i \cos(latitude_i * \pi/180) * \cos(longitude_i * \pi/180)/I_j$$

$$y_j = \sum_i \cos(latitude_i * \pi/180) * \sin(longitude_i * \pi/180)/I_j$$

$$z_j = \sum_i \sin(latitude_i * \pi/180)/I_j$$

$$M_j^{lat} = \arctan(z_j, \sqrt{x_j^2 + y_j^2})/\pi * 180$$

$$M_j^{lon} = \arctan(y_j, x_j)/\pi * 180$$

.

We follow a similar procedure for point C. The database of cities comes from the world Urbanization Prospects database on urban agglomerations in the world with at least 750,000 inhabitants in 2010 to which we add hand collected city coordinates. However, instead of summing over each mine i, we sum over each city and weigh each city by its population in 1950.[10] We choose the earliest available year, because current population sizes may have been influenced by infrastructure itself. With weights, z_j becomes: $\sum_i \sin(latitude_i * \pi/180) * p_i/I_j$ where p_i is the population of each city i and $I_j = \sum_i p_i$, the total population of the cities in country j. The midpoint of cities will therefore be relatively closer to the largest city, reflecting the fact that infrastructure that connects cities with the main port will be located mostly near larger cities.

Point P captures the location of the country's main commercial port. To identify this point for all countries in our sample, we proceed in several steps. First, we use the "World Port Ranking 2009" provided by the American Association of Port Authorities (AAPA) to infer the main container port in each country included in the ranking. For countries that are not included in the ranking, we used Maersk's website to track the port used by Maersk Line - the world's leading container shipping company - to import a container from Shanghai into the country's capital.[11] Finally, for countries that are neither in the AAPA ranking nor reached by a Maersk route, we identify the main commercial port by conducting a series of internet searches.[12] We coded as "port co-ordinates" those of the port's nearest city, which we got from the UN's 'World Urbanization Prospects' data set, and, for smaller cities, from Wikipedia/GeoHack.

To find point S, the point closest to the midpoint of the mines on the nearest coast, we rely on the "Global Self-consistent, Hierarchical, High-resolution Shoreline Database" (GSHHSD) provided by the National Oceanic and Atmospheric Administration (NOAA).[13] The database comes in four levels of detail (1 =land, 2 =lake, 3 =island in lake, 4 =pond in island in lake) and five resolutions. For our purpose it is best to use level 1 which excludes the possibility that we find S on the shoreline of a lake, and a low resolution which builds up the world's coastlines

[10] Results are robust to using current (2005) population.

[11] They have the largest market share (of 18%) according to http://www.shippingcontainertrader.com/facts.shtml.

[12] This led us to take Shanghai as the reference port for Kyrgystan, Tajikistan and Mongolia, Poti for Turmenistan and Uzbekistan, and St Petersburg for Kazakhstan.

[13] http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html

from 64,000 coordinates.[14] For each country, we calculate the distance between point M and each coastal coordinate and take the minimum. For example, the closest point on the coast S with respect to the midpoint M of mines in Argentina turns out to be on the coast of Chile, while point S for South African mines is only 50km from the actual port of Durban.

To accurately calculate the distance used in (6)-(8) we use navigation formulas.[15] The distances MP, MS, and CP are great circle distances.[16] To find the distance MI (the distance between M and I, where I is the point on the course from C to P that is nearest to point M) we use the great circle distance CM if point I lies behind the stretch CP, which is when IP>CP. If point I lies on CP, we use the absolute 'cross track error': $xte_{CMP} = |\arcsin(\sin(CM) * \sin(crs_{CM} - crs_{CP}))|$ (with coordinates in radians), where crs_{CM} is the course from C to M and crs_{CP} is the course from C to P.[17] Distance IP is then found by calculating the 'along track distance': $\arcsin(\sqrt{\{(\sin(CM))^2 - (\sin(xte_{CMP}))^2\}} / \cos(xte_{CMP}))$.

5 Results

5.1 Mining countries trade conditionally less with neighbors than with world markets

Table 5 reports the results of our main specification and the first piece of evidence in support of our hypothesis. For a world sample of bilateral trade (column (a)) we find the usual determinants of trade: it decreases in distance, but increases in country-pair characteristics that make trade easier, such as a common language, legal origin, a former colonial relationship and membership of trade agreements. An indicator for AsiaCaribbeanPacific (ACP) treatment of imports into the European Union (or preceding associations), which also includes many African former colonies, affects trade negatively. Head et al. (2011) found that the sign of this variable is very sensitive

[14] An intermediate level of detail would use 380,000 coordinates and quickly increase the time it takes to calculate distances.

[15] See http://williams.best.vwh.net/avform.htm

[16] I.e. the distance between C and P is equal to $\arccos(\sin(lat_c) * \sin(lat_p) + \cos(lat_c) * \cos(lat_p) * \cos(lon_c - lon_p))$ with coordinates in radians.

[17] These can be found as: $\mod(\arctan(\sin(lon_c - M^{lon}) * \cos(M^{lat}), \cos(lat_c) * \sin(M^{lat}) - \sin(lat_c) * \cos(M^{lat}) * \cos(lon_c - M^{lon})), 2\pi)$.

to the specification used. We find that it does increase trade for African countries in column (e). For our main variables of interest, N and NM, we find that a country is twice as likely to import from its neighbor (1.068*100%), but we also find that this is significantly decreasing in the number of mines, supporting our hypothesis that mine-related infrastructure biases trade in the direction of non-neighbors and world markets. Figure 4 summarizes this relationship. As we increase the number of mines in the destination country along the x-axis, we find that countries start to divert trade toward the rest of the world. Countries with 33 mines or more ($\exp 3.5$) (i.e. those listed in Table 1) do *not* import significantly more from their neighbors compared to countries with very few mines. In the extreme case of the US, which has the largest number of mines in the sample, we even find a negative effect on trade with its neighbors. The finding also holds if we exclude this extreme case in column (b) of Table 5.

OECD countries, which are sampled in column (c), do not trade significantly more with neighbors *and* it does not depend on mine related infrastructure. Also the effect of distance is smaller. This could imply that economically developed OECD countries are well enough connected with all trading partners through good roads, rail and ports. For the non-OECD destinations and African destinations we also find a trade re-direction effect, although it is not significant for the *average* country in Africa. Because the interaction is between a dummy and a continuous variable, the coefficient, its variance, and the covariance between N and NM determine a range for which also African countries do not trade significantly more with neighbors. This occurs if they have more than about 20 mines. However, looking at the illustrative maps of infrastructure in Africa suggests that this relationship may depend explicitly on the position of mines relative to urban centers and existing trade routes. This will be examined next.

5.2 How does the location of mines affect trade routes between cities and ports?

In Table 6 we report results where we include the triple interaction of neighbors' trade N with destination country mines M_d and destination country mine impact index α_d. The location of mines is exogenous with respect to the outcome variable and provides the second evidence in

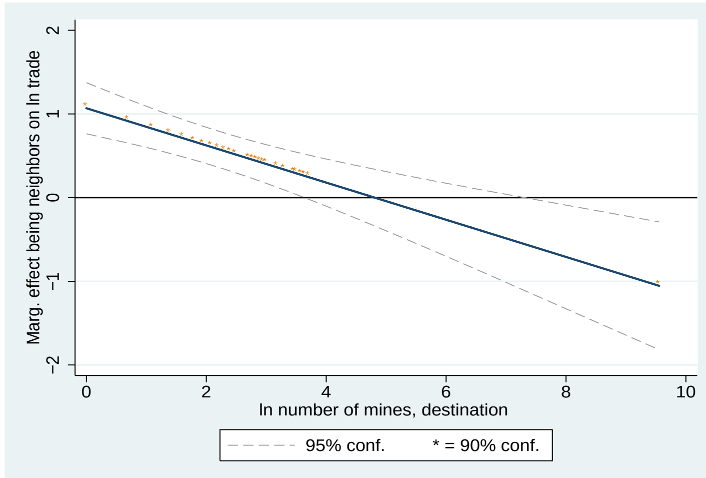


Figure 4: Marginal effect of reg. 5a (world sample)

favor of infrastructure as an explanation for our finding that mines lower trade costs with non-neighbors. To interpret the interactions we first calculate the marginal effect of a change in the number of mines in the destination country on bilateral trade between neighbors, and secondly derive the marginal effect of N on trade for a range of M and the two values of the mine impact index.

By setting $N = 1$ we focus initially on trade between neighbors. Due to the triple interaction between N, M_d and α_d, the size of the marginal effect, and its significance, will depend on the mine impact index α_d.[18]

$$\ln imp_{od} = \beta_1 N_{od} M_d + \beta_2 N_{od} M_d \alpha_d + \beta_3 N_{od} + a_o + a_d + \varepsilon_{od} \qquad (9)$$

[18]Consider the various components of the triple interaction $N_{od}M_d\alpha_d$. Terms N_{od} and $N_{od}M_d$ are included in equation 9, and so are terms M_d, α_d and $M_d\alpha_d$ (since they are absorbed by the destination fixed effect). We have also experimented with including the term $N_{od}\alpha_d$ in our regressions. When we do so, our results do not change, with the only exception that the negative coefficient on $N_{od}M_d\alpha_d$ for the Africa sample becomes non-significant (and the coefficient on $N_{od}\alpha_d$ is also negative and non significant). Nevertheless, the marginal effect graphs reveal a declining neighbor effect on trade as the number of mines increases, which is worse for countries with a high index value. We prefer not to include this term for the following two reasons. On one hand, there is no clear theoretical reason to include it. In fact, to do so would be equivalent to hypothesizing that the geographical location of mines - in the very specific sense implied by the index α_d - matters, *per se* - that is, independently on the number of mines - for how much a country trades with its neighbors. Also, this term may soak up much of the variation in $M_d\alpha_d$ in our Africa sample, and this may explain why the coefficient on $N_{od}M_d\alpha_d$ is less precisely estimated when we include it.

For trade between neighbors, the marginal effect to M_d equals:

$$\partial \ln imp_{od}/\partial M_d|_{N=1} = \hat{\beta}_1 + \hat{\beta}_2 \alpha_d \tag{10}$$

And its standard error follows as:

$$s.e. = \sqrt{\text{Var}\hat{\beta}_1 + \alpha_d^2 \text{Var}\hat{\beta}_2 + 2\alpha_d \text{Cov}(\hat{\beta}_1, \hat{\beta}_2)} \tag{11}$$

Figures 5, 6, and 7 display the marginal effect of M_d on bilateral imports between neighbors for a sample of world trade, non-OECD destinations and African destinations, respectively, with dashed 95% confidence bands. A $*$ denotes values significant at 90% confidence. Whereas for a world sample the index α_d does not change the interaction effect (which reflects the small β_2 coefficient in Table 6), we find that for non-OECD destinations and African destinations that the interaction is only significant and negative for countries where the mine location does affect city-port infrastructure ($\alpha_d = 1$). This implies that remote Chilean mines (with an π_d score of 0.06 that is below average) have much less influence on trade with neighbors than South African mines do (with an π_d score of 0.75 that is above average).[19]

In figures 8 and 9 we take a different look at the same regressions. We now take the derivative to N (as we did for figure 4) and calculate the marginal effect as it depends on M (with asterisks now denoting 95% confidence). However, because of the interaction with α_d, we can draw a line for $\alpha_d = 0$ and a line for $\alpha_d = 1$. For a score of zero of M we automatically also have a zero score for the mine impact index and trade between neighbors is unaffected. However, as the number of mines increases along the x-axis trade is increasingly directed away from neighbors. The re-direction effect is stronger (given by a steeper line) for countries where city-port infrastructure is affected by mines. For a value of about 55 mines or more ($= \exp 4$), we find that countries do not trade more with neighbors than with non-neighbors. But if the index α_d equals one we find

[19] We have also experimented with changing the dependent variable to non-resource imports instead of total imports. We still find negative and significant effects of mines on trade with neighbors, and a significantly negative effect of the index interaction in the African sample as before. The negative effect is no longer significant for the average non-OECD, but the neighbor effect still disappears for non-OECD countries with many mines. However, the proposed infrastructure channel applies to both non-resource and resource imports which should each face lower transportation costs. Total trade is therefor our preferred dependent variable.

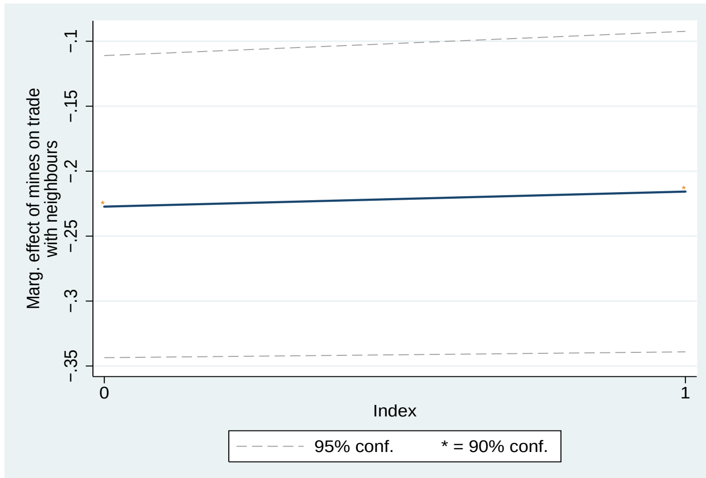


Figure 5: Marginal effect of reg. 6a (world sample)

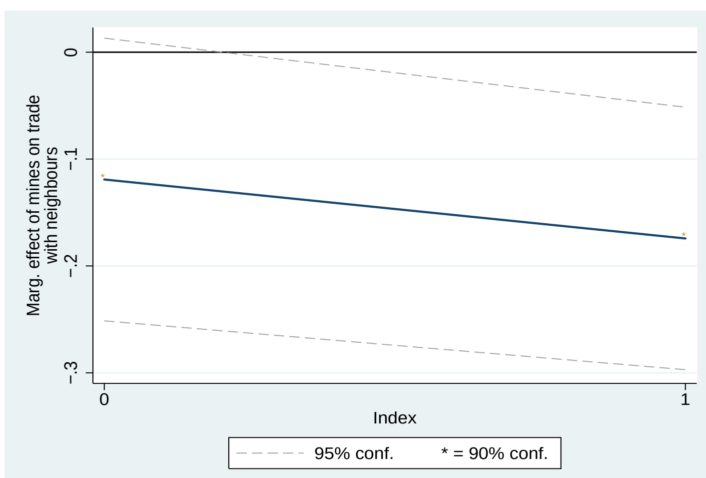


Figure 6: Marginal effect of reg. 6d (non-OECD sample)

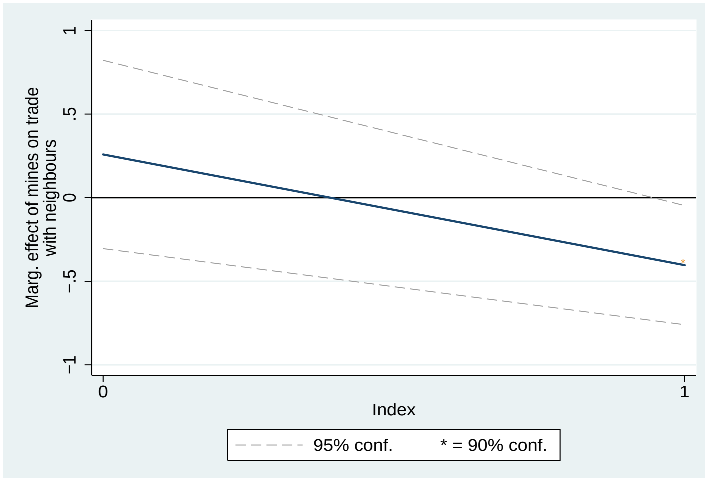


Figure 7: Marginal effect of reg. 6e (Africa sample)

that also countries with more than 27 mines (= exp 3.3) do not trade more with neighbors than with non-neighbors. The reason is that in these countries, the mines are positioned such that the required infrastructure to export the commodities improves existing trade routes between cities and ports, causing trade costs with the rest of the world to decline relative to trade costs with neighbors. In figure 9 we find a different pattern for African destinations. A relatively small number of 6 (= exp 1.8) mines causes the neighbor effect N on trade to become insignificant, but only if combined with a high index score (the dashed line). The fact that the latter effects is more apparent for Africa could provide an explanation for limited intra-African trade. The *upward* sloping line for $\alpha_d = 0$, which we investigate next, could be due to trade between landlocked countries and their transit neighbor, a feature that is relatively common in Africa.

5.3 Landlocked and transit countries

If infrastructure is the mechanism behind the asymmetric effect of mines, then we must find that landlocked countries import more from its transit neighbor. It is hard to think of an alternative story why landlocked countries would import more as a result of mines from transit neighbors over and above imports from the rest of the world. Therefor, we add controls for the fact that landlocked countries, as a result of mine related infrastructure, will have improved infrastructure with the coastal country it needs to transit to reach world markets. For example,

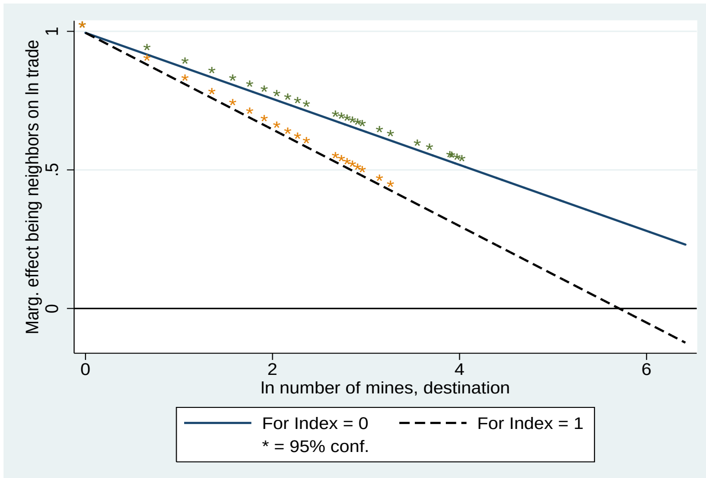


Figure 8: Marginal effect of N on trade, reg. 6d (non-OECD sample)

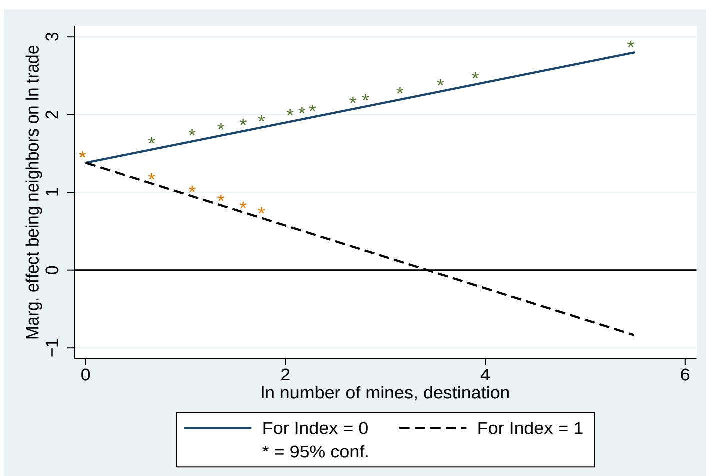


Figure 9: Marginal effect of of N on trade, reg. 6e (Africa sample)

Uganda's railway crosses Kenya to reach the sea. We therefor extend equation (9) with the terms NTL_dM_d and NT. The latter term captures the fact that neighbors share a transit connection will trade more with each other than other neighbors. We define T as a dummy equal to one if the two countries are in a transit relation and by L_d a destination landlocked dummy. For $T = L_d = 1$, we should find that if the landlocked country has many mines, it is able to import from its transit country at lower costs compared to a similar landlocked country with few mines. In that case $NTL_dM_d = NM_d$.

As before, we interpret the interactions graphically. Figures 10 and 11 summarize the findings of Table 7 for a sample of non-OECD and African destinations respectively.[20] The solid line in these figures represents the marginal effect of N on ln trade, similarly as in Figure 4, but for countries that are not in a transit relationship with another country. Again we find that for a higher number of mines that countries direct trade away from neighbors, to the extend that the positive neighbor effect on trade disappears. The dashed line graphs the marginal effect of N on imports by landlocked countries from their transit neighbors. As expected, the more mines these landlocked countries have, the more they import from their transit country. The difference between the solid and the dashed line is even starker in Africa (figure 11).

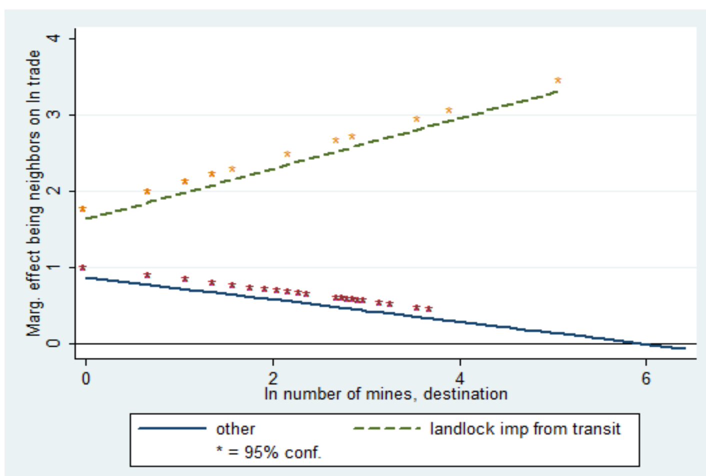


Figure 10: Marginal effect of N on trade, reg. 7d (non-OECD sample)

[20]We abstract from the effects of the mine impact index, because there are relatively few countries in a transit relationship and even fewer for which we also have information on the mine impact index, leaving too little variation to identify multiple interactions.

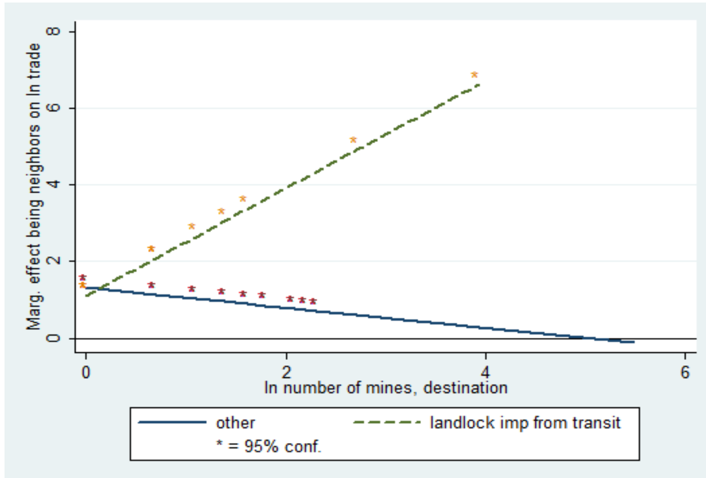


Figure 11: Marginal effect of of N on trade, reg. 7e (Africa sample)

Comparing Tables 5 and 7 we see that the value of M_d for which the neighbor effect on trade becomes insignificant drops for all samples once we take into account that some countries are transit countries and therefor trade more with neighbors as the number of mines increases.

5.4 Oil and gas fields should not affect infrastructure

Finally, our main hypothesis, that more mines leads to more outward infrastructure investment such that also importing from World markets becomes cheaper, rests on the assumption that such infrastructure can be used for both imports and resource exports. A natural falsification exercise is to investigate whether oil and gas fields, who's output is mostly piped, affects trade with particular trade partners. Moreover, we have have used mines of metals and other non-hydrocarbon minerals as a proxy for infrastructure. A potential problem with this assumption is that resource exports could in theory have asymmetric income effects as well, over and above the symmetric income effects (such as an increase in GDP) which are controlled for by origin and destination dummies. For example, if resource exports are mostly spent on luxury goods which are produced in World markets rather than in neighboring markets then this would also lead to a negative effect of mines on trade with neighbors.

We test the additional effect of oil and gas fields on imports from neighbors and non-neighbors. If both mines and oil and gas fields yield significant asymmetric effects on trade with neighbors then we may really be picking up an asymmetric income effect instead of our infrastructure channel. Since oil and gas is mainly transported across land through pipes, it is much less likely to be useful for imports, save for a possible effect from maintenance and access roads. Therefor, if infrastructure is the dominant channel, we should find that *only* mines affect trade with neighbors.

We extend our main regression with a measure of oil and gas fields. We use data from Horn (2003), who reports 878 on- and offshore oil and gas fields with a minimum pre-extraction size of 500 million barrels of oil equivalent (MMBOE), including year of discovery from 1868-2003, geographic coordinates and field size measures. This data set builds on previous data sets (e.g. Halbouty et al. 1970), and attempts to include every giant oilfield discovered around the world. Oil, condensate and gas are summed, with a factor of 1/.006 applied to convert gas trillion cubic feet to oil equivalent million barrels. We define OG_d as the log of the number of onshore fields plus one (since offshore fields should not affect overland infrastructure) and recalculate the index dummy α_d^{OG} measuring the likelihood of fields affecting connections between cities and ports, similarly as we did for mines. The top-20 countries with oil and gas fields are reported in Table 8 together with the index value π_d^{OG}. As before, we collapse the index into a dummy equal to one for values of π_d^{OG} lager than average, which is larger than 0.33.

The result is reported in Table 9, where the main regressions of Table 6 are augmented with the neighbor dummy interacted with OG_d and an interaction of the latter with α_d^{OG}. We still pick up a negative effect of mines on trade with neighbors in the World sample, the non-US sample and in Africa if $\alpha_d = 1$, while the affect for the non-OECD sample has become less significant. Importantly, we *do not* find a negative effect of oil and gas fields on trade with neighbors.[21] We conclude from this falsification exercise that mining infrastructure leads to a smaller neighbor effect on trade and that the main channel is infrastructure rather than any asymmetric income effects.

[21] Since the data on oil and gas fields also includes the field's pre-extraction size in millions of barrels of oil equivalent, we also experimented with redefining OG_d as the log of one plus the volume of reserves in the country. Also, we changed the calculation of the midpoint of oil and gas fields such that the midpoint is proportionally closer to larger fields. This led to qualitatively identical results. However, pre-extraction field size is probably only a rough measure of current field size.

6 Robustness

6.1 Do large countries trade more with neighbors?

The number of mines in a country depends on geology and exploration, but there is also the possibility that larger countries have more subsoil assets per se. For example, a simple log-linear regression of mines on surface area and income per capita yields a significant elasticity of surface area of 0.59. In turn, because of their size and long borders they may trade disproportionably with neighboring countries. This section explores this possibility by adding an interaction between the log of surface area in km^2 and the neighbor dummy to the main regressions, which we label NA_d. The result is given in Table 10. Larger countries do appear to trade more with neighbors than smaller countries (except in Africa), even while controlling for the average effect of distance, but this effect does not explain why we find a negative effect of mines on trade, further adding to the evidence in favor of the infrastructure channel.

6.2 'Zeros in trade' and 'zeros in mines'

Building on the recent literature on estimating trade flows allowing for the number of trading partners (Helpman et al., 2008) and the econometric literature on sample selection bias as a specification error (Heckman, 1979) we offer two-stage estimates of the determinants of both the external and internal margin in trade. We present this as a robustness exercise because we use a 2006 cross-section of trade with relatively few 'zero' observations which means that we loose few observations by taking the log of trade.[22] Within the sample bounded by the control variables we observe positive trade for 88 percent of possible trade flows, while for example Helpman et al. (2008) observe only 45 percent positive values in the 1986 cross section of bilateral trade flows.

To tackle the problem of zeroes in trade data, we correct for sample selection bias arising from omitted variables that measure the impact of the number of firms that engage in trade to a particular country. We adopt an agnostic approach and specify probit equations for the

[22]The raw COMTRADE data has only positive and missing observations. An alternative source, the IMF directions of trade database, reports mostly zeros where COMTRADE reports missing trade. We therefor assume that missing trade represents no trade in COMTRADE as well.

first stage to estimate the probability that a particular country exports to another country and use the resulting predictions in the second stage to estimate the determinants of bilateral trade. The advantage of this method is that the decision to enter foreign markets through exports and the amount of trade are determined separately. Alternative methods such as simple OLS on the selected sample of positive trade have to assume that both decisions are independent while a Tobit regression makes the strong assumption that both decisions can be captured by the same model. The nonlinear Poisson Pseudo Maximum Likelihood model proposed by Santos Silva and Tenreyro (2006) allows inclusion of both zero and non-zero trade flows and estimates the combined effect of the external and the internal margin, but tends to underestimate the number of zero flows, in addition to assuming homogenous coefficients for both entry and the amount of trade. We favor the two-stage method but report PPML estimates as well.

Although the two-step method is not necessary to obtain consistent estimates, an instrument is needed for otherwise the identification comes off the functional form assumption (normality). We thus need at least one variable that determines entry in foreign markets but does not also determine the volume of trade. We closely follow Helpman et al. (2008) who find evidence that the decision to export is well determined by measures of the cost of entry in a foreign market, while entry costs do not affect the amount of trade, based on a theoretical perspective that splits entry costs into fixed and variable costs and predicts that only the most productive firms can overcome the fixed costs. We offer a small improvement in that entry cost, proxied by a dummy variable equal to one if the combined amount of days and procedures it takes to start a business is above median, is measured in 1999 (Djankov et al., 2002) and is therefor more likely to affect 2006 trade than 1986 trade. We thus estimate the following two-stage model for non-resource FDI with the Heckman (1979) correction:

$$\Pr(\text{imp}_{od} > 0)|N_{od}M_d, N_{od}M_d\alpha_d, N_{od}, \ln\tau_{od}) = \Phi(\gamma_1 N_{od}M_d + \gamma_2 N_{od}M_d\alpha_d + \gamma_3 N_{od} + \gamma \ln\tau_{od}) \quad (12)$$

$$
\begin{aligned}
&\mathrm{E}[\ln \mathrm{imp}_{od} | \mathrm{imp}_{od} > 0, N_{od}M_d, N_{od}M_d\alpha_d, N_{od}, \ln \tau_{od}, a_o, a_d] = \\
&\qquad = k - \ln \tau_{od} + a_o + a_d + \beta_1 N_{od}M_d + \beta_2 N_{od}M_d\alpha_d + \beta_3 N_{od} + \\
&\qquad + \rho_{od}\sigma_{od}\phi_{od} + \upsilon_{od} \qquad (13)
\end{aligned}
$$

where $\Phi(.)$ indicates the cumulative normal density function and ρ_{od} are the correlations between unobserved determinants of decisions to enter into trade and unobserved determinants of trade once entry has occurred. The term $\phi_{od} = \varphi(.)/[1 - \Phi(.)]$ denotes the inverse Mills ratio, where $\varphi(.)$ denotes the standard normal density function. This ratio is included in the second stage (13) to correct for sample selection bias and is calculated from the estimated parameters of the first stage (12). By including the inverse Mills ratio in the second stage, estimating the coefficients and realizing that the standard deviation σ_{od} cannot be zero, the null hypothesis that $\rho_{od}\sigma_{od} = 0$ is equivalent to testing for sample selectivity.

Table 11 reports the result. For each region we report the first stage probit that determines entry into foreign markets, and the second stage regression with the inverse Mill's ratio. The latter is significant in all but the OECD sample where countries trade with most other countries. In each case the first stage shows that mines make it less likely that countries trade with neighbors at all, consistent with our infrastructure mechanism, and that entry costs correlate negatively with trade. Moving to the volume of trade in the second stage, we still find that mines lead to a smaller effect of sharing a border on trade. Again, we find that in Africa this effect is only significant and negative if mines are likely to improve the infrastructure between ports and cities.

For completeness, we also report the PPML estimates, which as explained above more restrictively assume the same model for both margins of trade. In this case the estimates are somewhat less significant as shown by Table 12.

Finally, we also address censoring of the variable M_d. Based on the notion that the existence of subsoil assets - and therefor mines - depends mostly on geology which is essentially random, we have added one unit to the count variable of the number of mines to prevent selection on a sample with only non-zero mines. The second rationale is that it is unlikely that any country truly has no mine at all and that it is due to random measurement error that some countries do not appear in the MRDS data. We perform a final check and regress trade on an interaction with neighbor and mines, where mines is the log number of mines as reported by the US Geological Survey. Panel A includes only NM_d and Panel B also $NM_d\alpha_d$. Selecting only countries with at least one mine leads to a sample reduction from 23120 to 16318, a reduction of 29 percent. Nevertheless, we still observe significant trade re-direction, which in Africa depends on the index, as before.

7 Discussion

We use this section to summarize, and try to rule out, possible alternative explanations for our results. We begin by discussing the result that countries with more mines trade less then average with neighbors (β_1 negative), and we will then turn to the fact that this effect is found to be stronger in countries where mines are more concentrated around cities (β_2 negative).

Our interpretations for a negative β_1 is that countries with many mines will have a good transport infrastructure put in place to serve the mining sector, but that can, at least in part, be used by other sectors as well. Because developing countries mostly export their mineral resources to faraway countries, such infrastructure will be biased in favor of overseas trade (and against overland trade), penalizing imports from neighbors vis-a-vis imports from the rest of the world.

An alternative explanation is that developing countries with a larger number of mines have more intense trade relations with industrialized countries and, since the latter are mostly overseas, their imports are biased in favor of the rest of the world. For example, it could be that these are the result of investment in exploration in colonial times. To the extent that such special relations continue to bias the pattern of trade in favor of imports from industrial countries, this would also show up as a negative β_1 in our regressions. We believe we address this possibility rather well by controlling for a good number of country-pair characteristics, including (preferential) trade agreements, a former colonial relationship and a common language.

It could also be that mineral resources are largely extracted by multinational companies headquartered in industrialized countries. It could then be that these companies tend to import large amount of equipment from their country of origin, biasing the local country's pattern of trade in favor of overseas countries.

However, neither of these alternative explanations can account for the fact that our trade re-direction effect is shown to depend on the geographical location of mines. First, we find some evidence that our trade re-direction effect is stronger, in countries where mines are located in such a way, so as to create transport infrastructure with more trade re-direction potential ($\beta_2 < 0$). Second, we find strong evidence that the trade re-direction effect is actually *inverted* for countries in a transit relation. That is, landlocked countries with a larger number of mines import *more* from their transit neighbor (less from all other neighbors), while transit countries import more from the landlocked country that they service, the larger is the number of mines that the latter has. While it would be hard to reconcile these findings with any of the above-described alternative explanations, they are perfectly compatible with our interpretation based on infrastructure: landlocked countries with a larger number of mines develop a better infrastructure connecting them to the port from where the product of these mines get shipped; but because this infrastructure can be used by other trades as well, this result in a higher trade with both the rest of the world, and the transit country.

8 Welfare

So far, we have not discussed the welfare implications of our findings. Although we find evidence for trade re-direction as a result of infrastructure built for mining, this does not imply that mines have no positive effect on the welfare of the country, or even on its regional trade partners. This is for at least two reasons.

First, mine-related infrastructure may result in a reduction in the transport costs that the country faces. While our result suggest that such reduction will be biased in favor of specific trade routes, there will still be a positive effect on terms-of-trade and national welfare.

Second, it may well be the case that mine-related infrastructure increases imports from *all* of the country's trading partners, including those that are connected via overseas routes. To see this, notice that our result that, on average, countries with more mines have a smaller neighbor effect, does not necessarily imply that they import less from neighbors in absolute terms, relative to countries with fewer mines. This is because all of our specifications include fixed effects which absorb any effect that mine-related infrastructure may have on average imports. Thus, it may be the case that, while countries with more mines import less from neighbors in percentage term - relative to countries with fewer mines - they import more in absolute terms. This would be the case if mine-related infrastructure results in a positive (although less pronounced) reduction in transport costs along overland routes as well, or if natural resource export revenue is spent on imports.

This been said, we still believe that the construction of mine-related infrastructure may potentially be associated with negative welfare effects. On one hand, regional trading partners who are connected to the home country via an overland route stand to suffer from the trade re-direction generated by mine-related infrastructure, while they do not stand to gain directly from a reduction in transport costs on the home country's overseas route. For them, the possibility that mine-related infrastructure is welfare improving relies entirely on the possibility that transport costs are reduced on the overland route as well, to such an extent as to compensate for the trade re-direction effect. While our results do not allow us to rule that out, there is certainly a stronger case for these regional trading partners to suffer from the construction of mine-related infrastructure in the home country. Regions where many adjacent countries develop a large stock of mine-related infrastructure may then end up being internally fragmented, as is clearly the case in Africa.

On the other hand, the construction of mine-related infrastructure may have negative dynamic consequences on manufacturing activity in the home country as well. This is because mine-related infrastructure increases the home country's integration with the advanced economies in the rest of the world, relative to market integration with regional economies at a similar level of development. This may trigger or accelerate a process of trade-related de-industrialization, as described by Grossman and Helpman (1991).

9 Conclusions

Natural resource windfalls may have a positive effect on regional trade, since a share of the new foreign exchange that they bring in may be spent on regionally produced goods. This income effect of resource windfall is often considered as a crucial mechanism though which the wealth of natural resources may be spread to the region a country belongs to.

In this paper, we have document that natural resource discoveries may also have a negative impact on regional trade. By leading to the creation of transport infrastructure that disproportionately decreases the cost of importing from overseas countries, resource discoveries may bias a country's structure of transport cost against imports from neighbors. We find strong evidence that countries endowed with more mines import less than average from neighbors, and use a variety of methods to establish that this is very likely to be due to the effect of resource-related infrastructure.

The development of a large regional market is normally seen as a key factor in triggering industrial take-off in developing countries. Still, many of the world's poorest regions - chief among which, Africa - are struggling to establish large regional markets, faced with extremely poor transport connections between neighboring countries. Our results suggests one potentially important reason for this state of affairs. In many developing countries, natural resource exports are a vital source of foreign exchange, and to encourage them is a priority of cash-starved governments. We have shown that, by encouraging the creation of an unbalanced network of transport infrastructure, this may have a direct negative impact on the possibility to create large regional markets, at least in the medium run. It is interesting to notice that, in the case of Africa, this problem is likely to be exacerbated by the recent, massive inflows of Chinese investments in transport infrastructure. This is because Chinese investments are known to prioritize the export of natural resources (and the import of Chinese products in return), and are therefore likely to result in strong trade re-direction.

Before concluding, one word of caution is in order. While we believe that the trade re-direction effect of natural resource discoveries may have a negative impact on long-run development by reducing the scope for regional integration, we cannot of course conclude that resource-related infrastructure is bad for the country where it is built. In fact, particularly in the short run, this country is likely to benefit from enjoying a better access to world markets, that allows for a better allocation of the foreign exchange windfall. The main point of the paper, however, remains: resource-related infrastructure may be detrimental to regional trade integration, and this is something that we must be aware of when estimating the broader welfare impact of natural resource discoveries.

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Appendices

A Figures

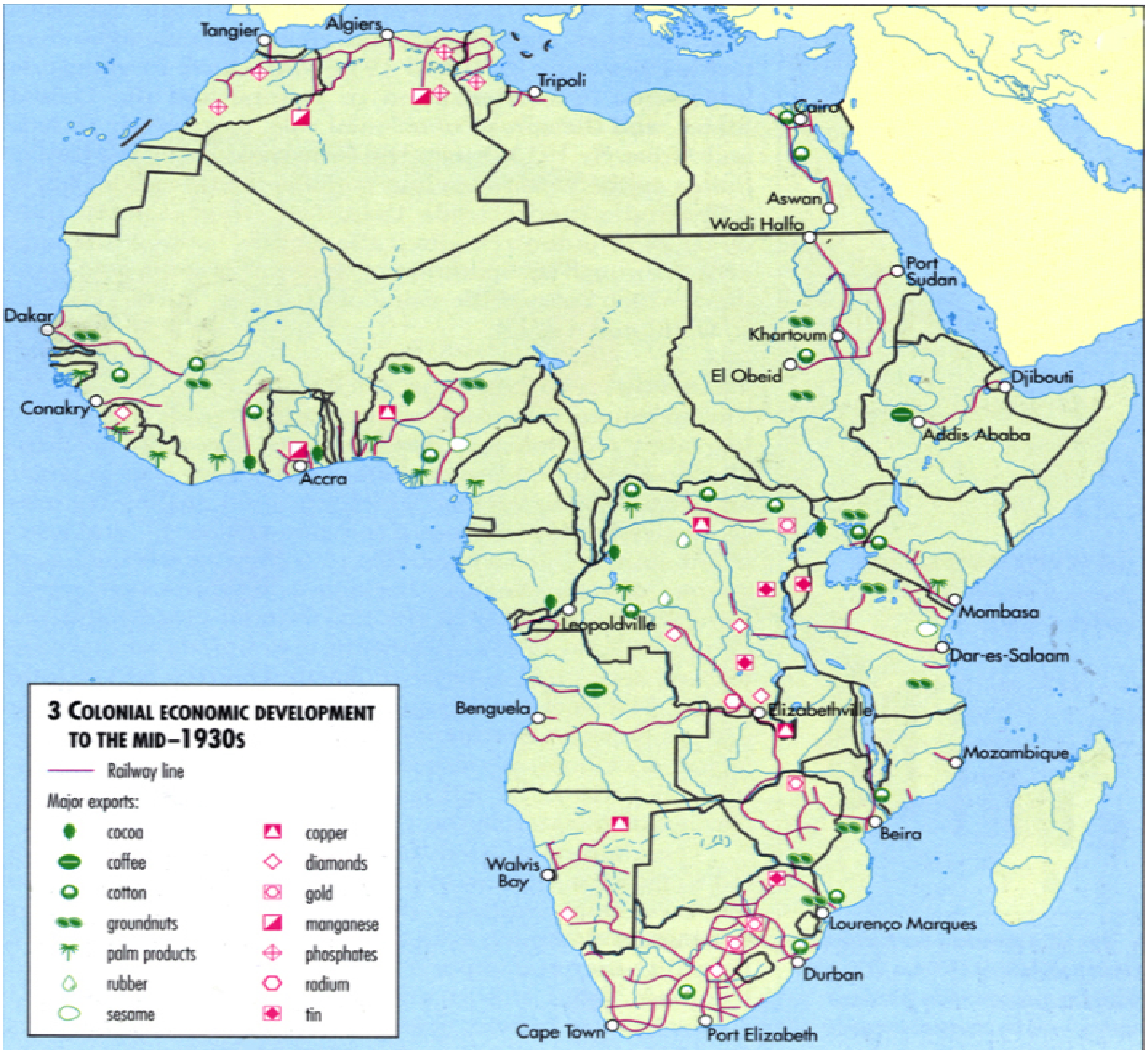


Figure 12: African colonial railways, 1930s.

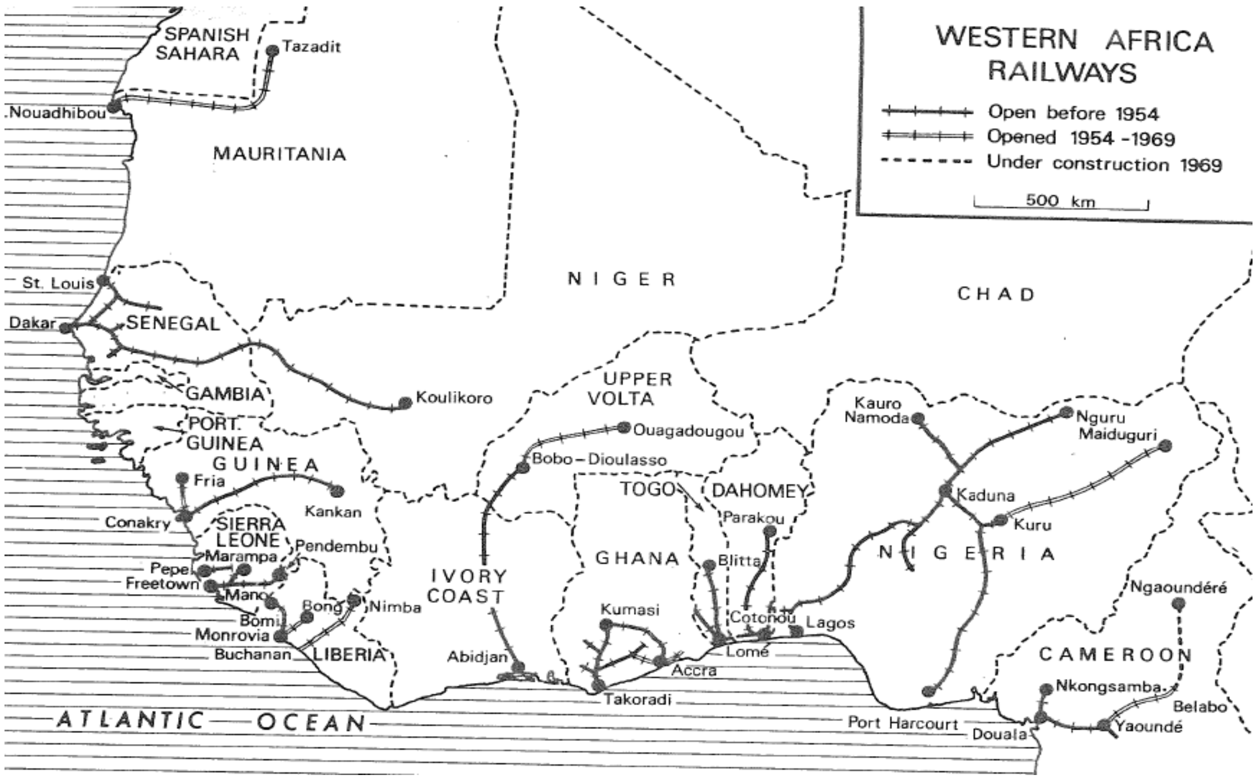
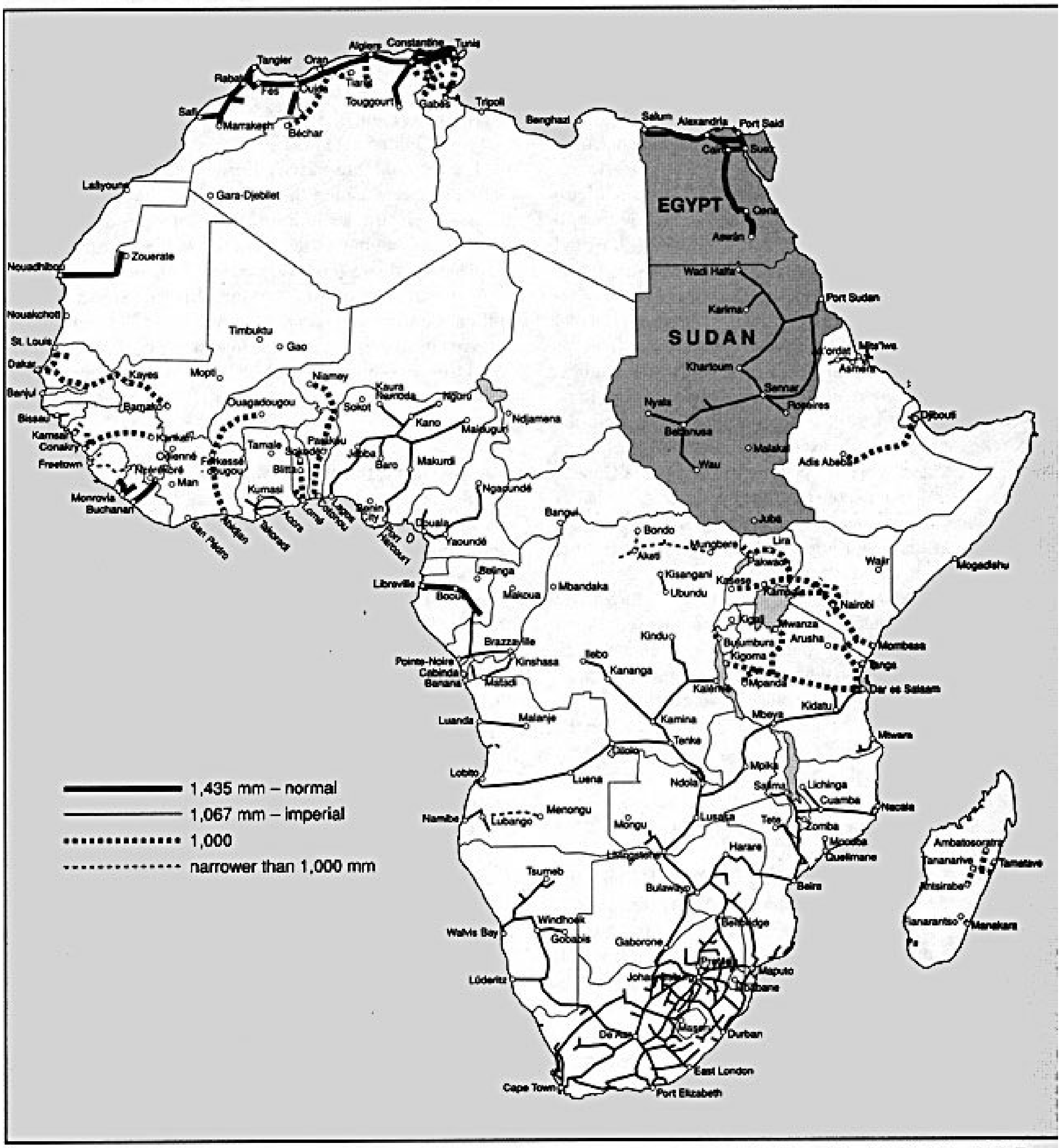


Figure 13: West African colonial railways, 1960s.

B Tables

The state of African railways in 1990



Sources: Fusion Energy Foundation, *The Industrialization of Africa*, Wiesbaden: Campaigner Publications, 1980; *The Times Atlas of the World*, New York: Times Books, 1990.

Figure 14: African railways, 1990s.

Table 5: Evidence for bias in the direction of trade

Dep. Var. = ln trade	(a) World	(b) non-US	(c) OECD	(d) non-OECD	(e) Africa
NM_d	-0.222***	-0.224***	-0.135	-0.148***	-0.144
	(0.051)	(0.052)	(0.097)	(0.053)	(0.184)
N	1.068***	1.059***	0.184	0.990***	1.258***
	(0.156)	(0.157)	(0.337)	(0.164)	(0.314)
ln distance	-1.545***	-1.551***	-1.332***	-1.585***	-1.759***
	(0.027)	(0.027)	(0.070)	(0.030)	(0.093)
Shared language	0.875***	0.888***	0.253**	0.895***	0.786***
	(0.054)	(0.054)	(0.123)	(0.059)	(0.103)
Shared legal	0.341***	0.347***	0.485***	0.320***	0.079
	(0.037)	(0.037)	(0.074)	(0.041)	(0.082)
ColHist	0.856***	0.860***	0.902***	0.946***	1.283***
	(0.101)	(0.102)	(0.152)	(0.123)	(0.236)
RTA	0.531***	0.517***	-0.105	0.867***	0.393***
	(0.058)	(0.058)	(0.129)	(0.072)	(0.151)
Both WTO	0.340***	0.346***	2.596***	0.335**	-0.194
	(0.128)	(0.128)	(0.536)	(0.132)	(0.240)
Shared currency	0.234	0.248*	-0.351**	1.102***	1.283***
	(0.145)	(0.146)	(0.158)	(0.194)	(0.268)
ACP	-0.216***	-0.220***		-0.349***	0.337*
	(0.071)	(0.071)		(0.073)	(0.195)
$\partial \ln imp/\partial N = 0$ for					
$M_d \geq$	3.7	3.6	0	4.4	3.6
Observations	23,122	22,933	5,063	18,059	5,571
R-squared	0.730	0.727	0.805	0.697	0.679

Note: N = neighbour; NM_d = Neighbour * mines in the destination country. Origin and destination fixed effect included. Robust standard errors in parentheses: *** p< 0.01, ** p< 0.05, * p< 0.1. non-US sample excludes the US as a destination. OECD sample is OECD destinations only and non-OECD excludes OECD countries as destinations. Africa sample refers to bilateral trade flows for which the destination is Africa.

Table 6: Bias in the direction of trade and mine impact dummy

Dep. Var. = ln trade	(a) World	(b) non-US	(c) OECD	(d) non-OECD	(e) Africa
NM_d	-0.227***	-0.231***	-0.138	-0.119*	0.259
	(0.059)	(0.062)	(0.095)	(0.067)	(0.287)
$NM_d\alpha_d$	0.012	0.015	0.030	-0.055	-0.662**
	(0.068)	(0.070)	(0.136)	(0.075)	(0.292)
N	1.066***	1.057***	0.158	0.995***	1.380***
	(0.156)	(0.157)	(0.363)	(0.164)	(0.305)
ln distance	-1.545***	-1.551***	-1.332***	-1.585***	-1.758***
	(0.027)	(0.027)	(0.070)	(0.030)	(0.094)
Shared language	0.875***	0.888***	0.254**	0.895***	0.787***
	(0.054)	(0.054)	(0.124)	(0.059)	(0.103)
Shared legal	0.341***	0.347***	0.485***	0.320***	0.081
	(0.037)	(0.037)	(0.074)	(0.041)	(0.082)
ColHist	0.857***	0.861***	0.900***	0.938***	1.267***
	(0.101)	(0.102)	(0.152)	(0.124)	(0.235)
RTA	0.531***	0.517***	-0.104	0.868***	0.385**
	(0.058)	(0.058)	(0.129)	(0.072)	(0.152)
Both WTO	0.340***	0.347***	2.595***	0.333**	-0.191
	(0.128)	(0.128)	(0.536)	(0.132)	(0.240)
Shared currency	0.234	0.248*	-0.352**	1.103***	1.294***
	(0.145)	(0.146)	(0.159)	(0.194)	(0.267)
ACP	-0.216***	-0.220***		-0.349***	0.323*
	(0.071)	(0.071)		(0.073)	(0.195)
$\partial \ln imp/\partial N = 0$ for $\alpha_d = 1$ & $M_d \geq$	3.5	3.5	0	3.6	2.1
Observations	23122	22933	5063	18059	5571
R-squared	0.730	0.727	0.805	0.697	0.680

Note: N = neighbour; NM_d = Neighbour * mines in the destination country; $NM_d\alpha_d$ = NM_d * infrastructure dummy in the destination country. Origin and destination fixed effect included. Robust standard errors in parentheses: *** p< 0.01, ** p< 0.05, * p< 0.1. non-US sample excludes the US as a destination. OECD sample is OECD destinations only and non-OECD excludes OECD countries as destinations. Africa sample refers to bilateral trade flows for which the destination is Africa.

Table 7: Larger bias in the direction of trade for non-transit countries

Dep. Var. = ln trade	(a) World	(b) non-US	(c) OECD	(d) non-OECD	(e) Africa
NM_d	-0.218***	-0.220***	-0.135	-0.146***	-0.259
	(0.050)	(0.052)	(0.097)	(0.052)	(0.179)
N	0.960***	0.951***	0.205	0.869***	1.310***
	(0.157)	(0.159)	(0.343)	(0.164)	(0.315)
NTL_dM_d	0.415	0.414	0.253	0.478*	1.662***
	(0.265)	(0.266)	(0.188)	(0.256)	(0.395)
NT	0.683*	0.685*	-0.495*	0.759*	-0.202
	(0.396)	(0.397)	(0.261)	(0.445)	(0.726)
ln distance	-1.546***	-1.551***	-1.332***	-1.586***	-1.761***
	(0.027)	(0.027)	(0.070)	(0.030)	(0.093)
Shared language	0.878***	0.891***	0.256**	0.900***	0.790***
	(0.054)	(0.054)	(0.124)	(0.059)	(0.103)
Shared legal	0.339***	0.345***	0.486***	0.319***	0.085
	(0.037)	(0.037)	(0.074)	(0.041)	(0.082)
ColHist	0.855***	0.859***	0.897***	0.934***	1.293***
	(0.101)	(0.101)	(0.152)	(0.124)	(0.235)
RTA	0.528***	0.514***	-0.105	0.864***	0.387**
	(0.058)	(0.058)	(0.129)	(0.072)	(0.150)
Both WTO	0.343***	0.349***	2.595***	0.339**	-0.195
	(0.128)	(0.128)	(0.536)	(0.132)	(0.240)
Shared currency	0.215	0.228	-0.354**	1.066***	1.257***
	(0.144)	(0.146)	(0.159)	(0.193)	(0.266)
ACP	-0.217***	-0.221***		-0.350***	0.335*
	(0.071)	(0.071)		(0.073)	(0.195)
$\partial \ln imp/\partial N = 0$					
for non-transit & $M_d \geq$	$3.3 \& \leq 3.6$	3.3	0	3.9	2.7
Observations	23122	22933	5063	18059	5571
R-squared	0.730	0.727	0.805	0.697	0.680

Note: N = neighbor; NM_d = neighbor * mines in the destination country; NTL_dM_d = neighbor and transit * a dummy equal to one for landlocked destination countries * mines in the destination country; NT = neighbor and transit. Origin and destination fixed effect included. Robust standard errors in parentheses: *** $p< 0.01$, ** $p< 0.05$, * $p< 0.1$. non-US sample excludes the US as a destination. OECD sample is OECD destinations only and non-OECD excludes OECD countries as destinations. Africa sample refers to bilateral trade flows for which the destination is Africa.

Table 8: Top countries with onshore oil and gas fields

Country	onshore fields	π_d^{OG}	Country	onshore fields	π_d^{OG}
Russia	143	0.11	Canada	13	0.05
United States	78	0.24	Nigeria	13	0.02
Iran	53	0.03	Algeria	12	0.48
Saudi Arabia	41	0.11	Uzbekistan	11	0.55
Iraq	26	0.63	Oman	10	0.19
Libya	23	0.20	United Arab Emirates	10	0.07
China	21	0.51	Kazakhstan	9	0.17
Venezuela	20	0.55	Kuwait	8	0.76
Mexico	15	0.01	Indonesia	8	0.30
Turkmenistan	14	0.76	Colombia	7	0.42

Table 9: Mines and oil and gas fields

Dep. Var. = ln trade	(a)	(b)	(c)	(d)	(e)
	World	non-US	OECD	non-OECD	Africa
NM_d	-0.231***	-0.233***	-0.218	-0.088	0.244
	(0.070)	(0.072)	(0.184)	(0.077)	(0.290)
$NM_d\alpha_d$	0.034	0.037	0.104	-0.053	-0.616**
	(0.074)	(0.075)	(0.168)	(0.080)	(0.293)
NOG_d	0.038	0.041	0.219	-0.059	-0.139
	(0.091)	(0.091)	(0.392)	(0.092)	(0.200)
$NOG_d\alpha_d^{OG}$	-0.199	-0.200	-0.537	-0.136	-0.282
	(0.146)	(0.146)	(0.607)	(0.146)	(0.385)
N	1.090***	1.078***	0.271	1.038***	1.455***
	(0.159)	(0.160)	(0.418)	(0.169)	(0.336)
Observations	23122	22933	5063	18059	5571
R-squared	0.730	0.727	0.805	0.697	0.680

OG_d equals log of the number of onshore oil and gas fields in the destination country +1. α_d^{OG} is the mine impact index calculated on the basis of onshore oil and gas fields.

Table 10: Large countries trade more with neighbors

Dep. Var. = ln trade	(a) World	(b) non-US	(c) OECD	(d) non-OECD	(e) Africa
NM_d	-0.334***	-0.342***	-0.599***	-0.199***	0.229
	(0.068)	(0.070)	(0.226)	(0.077)	(0.290)
$NM_d\alpha_d$	-0.000	0.005	-0.047	-0.060	-0.673**
	(0.069)	(0.070)	(0.126)	(0.076)	(0.294)
NA_d	0.174***	0.177***	0.806**	0.121**	0.108
	(0.052)	(0.052)	(0.357)	(0.054)	(0.137)
N	-0.883	-0.927	-8.475**	-0.367	0.022
	(0.605)	(0.605)	(3.809)	(0.622)	(1.780)
Observations	23120	22931	5063	18057	5571
R-squared	0.730	0.727	0.805	0.697	0.680

NA_d equals an interaction between neighbor and the log area in km2 of the destination country.

Table 11: Heckman 2-step estimation

Sample:	World		non-US		OECD		non-OECD		Africa	
Method:	probit	OLS	probit	OLS	probit	OLS	probit	OLS	probit	OLS
Dep. var. is trade in:	$\in (0,1)$	ln	$\in (0,1)$	ln	$\in (0,1)$	ln	$\in (0,1)$	ln	$\in (0,1)$	ln
	1st stage		1st stage		1st stage		1st stage		1st stage	
NM_d	-0.017***	-0.235***	-0.018***	-0.239***	-0.004***	-0.132	-0.024**	-0.141**	-0.021**	0.191
	(0.006)	(0.062)	(0.006)	(0.062)	(0.001)	(0.110)	(0.010)	(0.066)	(0.010)	(0.295)
$NM_d\alpha_d$	-0.002	0.013	-0.002	0.017	-0.003**	0.039	0.014	-0.043	0.015	-0.629**
	(0.008)	(0.068)	(0.009)	(0.068)	(0.001)	(0.131)	(0.014)	(0.076)	(0.013)	(0.293)
N	-0.023*	1.062***	-0.024*	1.052***	0.014***	0.154	-0.064**	0.949***	0.005	1.460***
	(0.014)	(0.172)	(0.014)	(0.172)	(0.004)	(0.390)	(0.025)	(0.173)	(0.011)	(0.289)
ln distance	-0.053***	-1.564***	-0.054***	-1.572***	-0.002***	-1.325***	-0.098***	-1.658***	-0.033***	-1.931***
	(0.003)	(0.031)	(0.003)	(0.031)	(0.001)	(0.071)	(0.004)	(0.034)	(0.004)	(0.096)
Shared language	0.031***	0.892***	0.031***	0.907***	0.002	0.244*	0.056***	0.946***	0.027***	0.901***
	(0.003)	(0.059)	(0.003)	(0.059)	(0.001)	(0.126)	(0.006)	(0.063)	(0.004)	(0.105)
Shared legal	0.010***	0.345***	0.011***	0.351***	0.001*	0.478***	0.018***	0.333***	0.004	0.116
	(0.002)	(0.040)	(0.002)	(0.040)	(0.001)	(0.075)	(0.004)	(0.044)	(0.003)	(0.083)
ColHist	0.006	0.854***	0.006	0.858***	0.003	0.896***	-0.029	0.902***	0.239***	1.180***
	(0.016)	(0.127)	(0.017)	(0.128)	(0.002)	(0.160)	(0.044)	(0.133)	(0.031)	(0.246)
RTA	0.041***	0.521***	0.043***	0.506***	0.017***	-0.105	0.064***	0.877***	0.011*	0.313**
	(0.007)	(0.066)	(0.007)	(0.067)	(0.003)	(0.129)	(0.012)	(0.080)	(0.006)	(0.154)
Both WTO	0.010**	0.327**	0.010**	0.332**	-0.001	2.619***	0.013	0.316**	0.019***	-0.130
	(0.005)	(0.139)	(0.005)	(0.139)	(0.004)	(0.533)	(0.008)	(0.140)	(0.007)	(0.240)
Shared currency	0.008	0.230	0.008	0.243	0.001	-0.351**	0.011	1.181***	-0.008	1.316***
	(0.008)	(0.176)	(0.009)	(0.178)	(0.003)	(0.163)	(0.015)	(0.213)	(0.008)	(0.274)
ACP	-0.025***	-0.189***	-0.025***	-0.192***			-0.043***	-0.287***	-0.035**	0.463**
	(0.007)	(0.072)	(0.007)	(0.072)			(0.013)	(0.074)	(0.016)	(0.198)
Entry costs	-0.006*		-0.006*		0.001		-0.014**		-0.008*	
	(0.003)		(0.003)		(0.001)		(0.006)		(0.005)	
Inverse Mill's ratio		0.194**		0.211**		-0.389		0.584***		1.362***
		(0.087)		(0.088)		(0.362)		(0.098)		(0.162)
% zero trade	22%		23%		8%		26%		28%	
Observations	29783	23122	29592	22933	5476	5063	24307	18059	7694	5571
R-squared		0.730		0.727		0.805		0.698		0.685

Note: Entry costs is a dummy equal to one if the sum of the number of days and procedures that are necessary to start a business are above median. N = neighbour; NM_d = Neighbour * mines in the destination country; $NM_d\alpha_d = NM_d$ * infrastructure dummy in the destination country. Trade-pair clustered standard errors in parentheses: *** p< 0.01, ** p< 0.05, * p< 0.1. non-US sample excludes the US as a destination. OECD sample is OECD destinations only and non-OECD excludes OECD countries as destinations. Africa sample refers to bilateral trade flows for which the destination is Africa.

Table 12: Poisson PMLE estimates

Dep. var.= trade, with .=0	(a)	(b)	(c)	(d)	(e)
Panel A	World	non-US	OECD	non-OECD	Africa
NM_d	-0.000	-0.061*	0.012	-0.152***	-0.213**
	(0.026)	(0.034)	(0.026)	(0.036)	(0.096)
N	0.291***	0.412***	0.397***	0.680***	1.162***
	(0.112)	(0.124)	(0.121)	(0.158)	(0.324)
Panel B	World	non-US	OECD	non-OECD	Africa
NM_d	0.000	-0.064*	0.013	-0.166***	-0.192*
	(0.026)	(0.038)	(0.026)	(0.039)	(0.113)
$NM_d\alpha_d$	-0.011	0.014	-0.006	0.030	-0.027
	(0.033)	(0.035)	(0.034)	(0.036)	(0.111)
N	0.301***	0.405***	0.404***	0.679***	1.162***
	(0.116)	(0.124)	(0.125)	(0.157)	(0.324)
% zero trade	22%	23%	8%	26%	28%
Observations	29783	29592	5476	24307	7694

Note: N = neighbour; NM_d = Neighbour * mines in the destination country. Origin and destination fixed effect included. Robust standard errors in parentheses: *** p< 0.01, ** p< 0.05, * p< 0.1. non-US sample excludes the US as a destination. OECD sample is OECD destinations only and non-OECD excludes OECD countries as destinations. Africa sample refers to bilateral trade flows for which the destination is Africa.

Table 13: Observations with only non-zero mines

Dep. Var. = ln trade	(a)	(b)	(c)	(d)	(e)
Panel A	World	non-US	OECD	non-OECD	Africa
NM_d	-0.268***	-0.272***	-0.181*	-0.206***	0.004
	(0.056)	(0.058)	(0.094)	(0.062)	(0.240)
N	1.315***	1.310***	0.222	1.237***	1.079**
	(0.194)	(0.196)	(0.309)	(0.222)	(0.465)
Observations	16,318	16,129	4,347	11,971	3,857
R-squared	0.736	0.732	0.805	0.702	0.699

Panel B	World	non-US	OECD	non-OECD	Africa
N	-0.275***	-0.282***	-0.180*	-0.180**	0.341
	(0.064)	(0.067)	(0.093)	(0.075)	(0.327)
$NM_d\alpha_d$	0.016	0.020	-0.012	-0.050	-0.629**
	(0.069)	(0.070)	(0.136)	(0.076)	(0.310)
N	1.311***	1.306***	0.233	1.243***	1.261***
	(0.194)	(0.196)	(0.321)	(0.223)	(0.451)
Observations	16318	16129	4347	11971	3857
R-squared	0.736	0.732	0.805	0.702	0.700

Note: N = neighbour; NM_d = Neighbour * mines in the destination country. Origin and destination fixed effect included. Robust standard errors in parentheses: *** p< 0.01, ** p< 0.05, * p< 0.1. non-US sample excludes the US as a destination. OECD sample is OECD destinations only and non-OECD excludes OECD countries as destinations. Africa sample refers to bilateral trade flows for which the destination is Africa.