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From Mine to Coast:

Transport infrastructure and the direction of trade in developing countries

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Abstract

Mine-related transport infrastructure specializes in connecting mines to the coast, and not so much to neighboring countries. This is most clearly seen in developing countries, whose transport infrastructure was originally designed to facilitate the export of natural

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resources in colonial times. We provide first econometric evidence that mine-to-coast transport infrastructure matters for the pattern of trade of developing countries, and can help explaining their low level of regional integration. The main idea is that, to the extent that it can be used not just to export natural resources but also to trade other commodities, this infrastructure may bias a country's structure of transport costs in favor of overseas trade, and to the detriment of regional trade. We investigate this potential bias in the context of a gravity model of trade. Our main findings are that coastal countries with more mines import less than average from their neighbors, and this effect is stronger when the mines are located in such a way that the related infrastructure has a stronger potential to affect trade costs. Consistently with the idea that this effect is due to mine-to-coast infrastructure, landlocked countries with more mines import less than average from their *non-transit* neighbors, but more then average from their *transit* neighbors. Furthermore, this effect is specific to mines and not to oil and gas fields, arguably because pipelines cannot possibly be used to trade other commodities. We discuss the potential welfare implications of our results, and relate these to the debate on the economic legacy of colonialism for developing countries.

JEL Codes: F14, F54, Q32, R4.

Keywords: Mineral Resources, Transport Infrastructure, Regional Trade Integration, Gravity Model, Economic Legacy of Colonialism.

1 Introduction

The economic legacy of colonialism has attracted renewed attention in recent years, as a number of empirical papers have sought to test various theoretical arguments about the effect of colonial policies on contemporary economic performance (for two recent contributions, see Feyrer and Sacerdote, 2009, and Iyer, 2010). 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 colonizer. In the long-run, the argument goes, this led to an adverse pattern of specialization, whereby all high value-added activities are undertaken overseas, and the former colonies are bound to a condition of *dependency* on their former colonial masters (e.g. Dos Santos, 1970; Amin, 1972). Key to this result, it is claimed, was investment in transport infrastructure. Colonial rails and roads were constructed to connect the interior to the coast; they were intended to facilitate the export of raw materials and the import of European manufactures, and had nothing to do with the needs of local and regional trade (e.g. Rodney, 1982, p. 209).[1] By strengthening the comparative advantage of overseas manufactures, this infrastructure contributed to displacing existing local and regional producers. Colonial transport infrastructure has persisted over time, contributing to explain the former colonies' little regional integration and disappointing economic performance after decolonization.

A casual look at a map of colonial transport infrastructure immediately illustrates why this argument may have gained considerable popularity. Map 1 in Appendix A describes West and

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[1] A second key rationale of colonial investment in infrastructure was to facilitate the establishment of military and political control over the interior.

East African railways in the 1960s, the years following independence. The map clearly shows that colonial railways mostly connected the interior to the coast, while there were very few links connecting neighboring countries; furthermore, many of the latter links were designed primarily to connect the interior of a landlocked country to the coast. Strikingly, this pattern seems to have remained unaltered in the thirty years following independence. Map 2 describes the structure of African railways in the 1990s, which appears to be very similar to those in the previous map. In Appendix B, we provide a case study of Ghana, a resource-rich country where the colonial transport infrastructure had a clear interior-to-coast pattern, and has persisted after decolonization.

While an interior-to-coast pattern of transport infrastructure does not *per se* allow us to conclude that such infrastructure is sub-optimal, such a conclusion actually permeates the contemporary trade and development literature. 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).[2] Sachs *et al.* (2004, p. 182) explicitly blame this on interior-to-coast transport infrastructure: “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

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[2] This is quite evident in the raw data: African countries were less than half as likely to import from neighbors than the average OECD country in 2006, and imported only a quarter of all their imports from other African countries (see Table 1 in Appendix D).

cross-border trade". The African Development Bank has recently taken up this challenge, by drafting an ambitious plan to improve the overland connections between Sub-Saharan African countries (Buys *et al.*, 2006).[3]

In this paper, we provide first econometric evidence that the current small volumes of regional trade in developing countries may be attributed to their specialization in the export of natural resources, and the related stock of interior-to-coast transport infrastructure. In particular, we focus on the impact of *mine-to-coast* infrastructure. Drawing inspiration from some of the arguments of dependency theorists, we formulate and test the following hypothesis. International specialization implies that developing countries tend to export their mineral resources to developed countries. Because developed countries are mostly located in overseas continents from the perspective of developing countries, such exports will require the construction of transport infrastructure connecting mineral-rich regions of the interior to the coast, and from there to overseas markets. Thus, we expect that developing countries with a larger number of active mines will have a larger and better stock of transport infrastructure (rail, roads, and ports) connecting their mines to the coast. To the extent that such infrastructure can also be used to import a broad set of goods, it will reduce the transport costs on import from overseas countries disproportionately more than on imports from regional trading partners. Furthermore, if such infrastructure has dominated national infrastructural investment (because of the long-run effect of colonial policies, or because of other reasons that we discuss below), these countries' *overall* structure of transport costs will also be biased in favor of imports from overseas countries. Thus, we expect that, on average, a larger number of active mines should result in "trade re-direction effect" in developing

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[3] The authors estimate that the realization of such a plan would expand overland trade by about $250 billion over 15 years, greatly outweighing the cost of initial upgrading and annual maintainance.

countries, favoring imports from overseas countries to the detriment of imports from regional trading partners.

We build our empirical strategy on the following steps. We begin by estimating 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, indeed, 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.[4] When we split the sample in OECD vs non-OECD destinations, we find that this trade re-direction effect disappears for the first group of countries, while it is still there for the second group of countries. This is *prima-facie* evidence in favor of our hypothesis, since we would have expected a larger number of mines to have a trade re-direction effect in developing countries, and in developing countries only.[5]

While we would like to test directly whether or not this trade re-direction effect of mines can be attributed to the 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 therefore use a number of strategies to test our hypothesis indirectly.

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[4] For example, we find that the positive neighbor effect on trade disappears altogether for the 40 most important mining countries.

[5] Developed countries will tend to retain a larger part of their mineral resources for domestic or regional consumption, and a larger number of mines will then be less likely to result in a network of transport infrastructure that is more biased in favor of overseas trade. Moreover, it is only in developing countries that the negative long-run impact of colonial investment should be apparent.

First, our hypothesis predicts that the trade re-direction effect should be stronger when the (exogenous) location of mines is such that the related transport infrastructure has a stronger impact on trade costs. For example, imagine to draw 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 the mine to have a large potential for trade re-direction, 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 re-direction potential' of a country's mines, and test for the prediction that, for a given number of mines, the trade re-direction effect is stronger in countries with a higher value of the index.

The second strategy derives from the existence of landlocked countries in our sample. Developing, landlocked countries 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 re-direction effect, such effect should disappear for imports from transit neighbors. This is because these countries benefit from the mine-to-coast transport infrastructure just as much as overseas countries do, if not more. We thus adopt a specification where we distinguish between transit and "normal" neighbors , and test for any difference in the trade re-direction effect between the two. We also expect that 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. This is based on the observation that, if mine-to-coast transport infrastructure is what is driving the trade re-direction effect of mines, this effect should disappear when we look at specific types of mineral resources that are unlikely to generate infrastructure that can be used by other trades as well. We therefore add the number of oil and gas fields to our main specification, on the premise that oil and gas, differently from other mineral resources, are mostly transported through pipelines.

We find compelling evidence in favor of our hypothesis. First, for a given number of mines in the destination country, we find that the trade re-direction effect is larger when the index measuring the trade re-direction potential of the country's mines is higher. In other words, the exogenous location of mines has an independent effect on the direction of national trade, and this is consistent with the existence 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. Next, we find that landlocked destination countries with a larger number of mines import less the average from their normal neighbors, but *more* than average from their transit neighbors. As expected, this effect holds only for (less developed) non-OECD countries. Finally, our falsification exercise yields the desired result: there is no trade re-direction effect associated with the number of oil and gas fields nor their location, 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 trade re-direction effect that penalizes regional trade. One must be very careful in drawing quick welfare implications from these results, however. For one thing, even if the interior-to-port transport infrastructure is biased in favor of imports from overseas countries, it will still decreases overall national transport costs. Since this will have positive welfare implications for domestic consumers and producers, we cannot draw any clear welfare implications for the country where the interior-to-coast transport infrastructure is built. Furthermore, we cannot conclude that developing countries with more mines trade less with 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.

Still, 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, such 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 transport costs.

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

2 Related literature

The paper is related to a growing literature on the impact of infrastructure on economic performance. A first group of papers have studied the long-term impact of infrastructure. For example, Banerjee *et al.* (2012) find that Chinese areas that were "treated" with a railway connection in late 19th century were somewhat richer in 1986, but did not benefit disproportionately from subsequent Chinese growth. Faber (2012) finds the construction of highways in China favored the concentration of industrial activity in larger locations, to the detriment of smaller ones. Jedwab and Moradi (2012) focus on the long-term impact of colonial railways in Ghana, finding that places that were connected by the railway are more developed today. A second group of papers have focused on the impact of infrastructure on market integration and welfare. Donaldson (2012) finds that colonial railroads in India had a major impact on trade integration between Indian regions and with the rest of the world, implying a positive welfare effect. Keller and Shiue (2008) find that railways had a stronger market integration effect on 19th century Europe than custom liberalizations and monetary unions.[6] We contribute to this literature by investigating the *asymmetric* market integration effect of transport infrastructure. Furthermore, while the above-mentioned literature focuses on exogenous variation in the placement of infrastructure, we explicitly test a hypothesis that relates the placement of infrastructure to a country's natural resources.

The idea that a country's natural resource production may adversely bias national trade patterns dates back to the so-called "Dependency School". This held that integration in the world

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[6] A third paper in this literature is Michaels (2008). The paper looks at the labor market effect of a decrease in trade costs within the US, as brought about by highway construction in the 1950s.

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 (1950) and Singer (1950), and became very influential in the 1960s and 1970s as an antithesis to modernization theories.[7] 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). 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."However, to the best of our knowledge, no other paper has systematically tested this with data on mines.

Our paper looks for evidence that developing countries' transport infrastructure - much of which was inherited from colonial times - biases this country's structure of international trade

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[7] See Dos Santos (1970) and Amin (1972) for details.

against regional integration. Because of this, the paper is related to the literature on the economic legacy of colonial empires. This has been very prolific in recent years, after the seminal paper by Acemoglu *et al.* (2001) argued that much of today's comparative development can be explained with different institutional investments made by colonizers in different colonies. Recent contributions include Nunn (2008), on the long-run consequences of the slave trade on Africa; Huillery (2009), on the long-run effects of public investment in colonial French Africa; and Iyier (2010) on the comparative long-run impact of direct versus indirect colonial rule in India. We contribute to this literature by looking at the long-run effect of colonial investment in *infrastructure*. Although Huilery (2009) and the above-mentioned studies by Banerjee *et al.* (2012) and Jedwab and Morady (2012) also look at this, we test for a *specific hypothesis* regarding the negative impact of colonial infrastructure on contemporary regional trade.

The literature on the pattern of intra-African trade has investigated the openness to trade of African countries among each other, relative to the standard provided by the gravity equation. For example, Limao and Venables (2001) find that trade between pairs of Sub-Saharan African (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,[8] this difference 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.

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

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

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 vs 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"):

$$\ln \mathrm{imp}_{od} = k - \ln \widetilde{\tau}_{od} + a_o + a_d + v_{od}, \tag{1}$$

where k is a constant, $\widetilde{\tau}_{od}$ is an index capturing all 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. Our goal is to determine how $\widetilde{\tau}_{od}$ will depend on the number of mines in d, for all possible o.

Consider first a world with a number of separate continents, but only coastal countries. A stylized image of such a world is represented in Figure 4, Panel I (Appendix C), which represents a destination country and n origin countries (o_i), both on the same continent as d ($i = 1, ..., 5$) and on separate continents or "overseas" ($i = 6, ..., n$). Overseas origin countries are connected to the destination country through a sea route, terminating at port P. The existence of mines in the destination country will normally be associated with the existence of mine-related transport infrastructure, some of which will be connecting the mines to foreign markets. In the figure, the potential location of such infrastructure is represented by all the lines that connect mine M to foreign countries.

Assume that the mine-related transport infrastructure connecting d to some o_i is usable by other trades as well, thus reducing d's cost of importing from o_i. The question then arises: on average, will this favor imports from all o_i in a roughly similar manner, or will it be systematically biased in favor of some o_i?

Assume that d is a developing country from now on. Developing countries export most of their natural resources to industrialized countries, and these are located overseas from the perspective of most developing countries. It follows that we expect d's mine-related infrastructure to be more likely to connect point M to point P - from where the natural resources can be shipped overseas - than to neighboring countries. In other words, we expect d's mine-related infrastructure to be likely to have a "mine-to-coast" trajectory. In Figure 4, this is represented by the fact that the line connecting M to P is thicker than the lines connecting M to neighboring countries.[9]

To the extent that d's imports from neighbors are less likely to be routed through P than imports from non-neighbors, one hypothesis that we may then put forward is that the mine-related transport infrastructure will be more likely to reduce transport costs on import from $i = 6, ..., n$ than on imports from $i = 1, ..., 5$. Because the same logic applies to each mine existing in d, we expect this effect of mine-related transport infrastructure to be stronger, the larger is the number of mines in d (the more points M there are).

Denote by $\phi^{\not{N}}$ the probability that the mine-related infrastructure connects point M to point P (that is, it has a mine-to-coast trajectory), and by ϕ^{N} the probability that it connects it to a neighboring country. We then expect that, if d is a developing country, $\phi^{\not{N}} > \phi^{N}$ should hold.[10] Next, suppose that we are able to construct an index $\alpha_d \in [0, 1]$, measuring the extent

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[9] Developing countries have also largely inherited their transport infrastructure from colonial times. Since colonizers were primarily interested in the export of natural resources, the mine-to-coast transport infrastructure is likely to *dominate* these countries' transportation system, resulting in the asymmetric pattern illustrated in Figure 4

[10] For developed countries, we expect these two probabilities to be very small (since developed countries tend to export a smaller proportion of their natural resources) and roughly similar to each other (since developed countries are both neighbors and non-neighbors from the perspective of many developed countries). Both factors suggests that the difference between $\phi^{\not{N}}$ and ϕ^{N} should be close to zero for developed countries.

to which the mine-to-coast transport infrastructure overlaps with the location of d's consumers (for example, with cities), and thus actually contributes to reducing their import costs. In the next section, we will construct this index in such as way as to exploit the location of mines as a source of exogenous variation. We then hypothesize that d's cost of importing from some o_i is determined as follows:

$$\ln \widetilde{\tau}_{od} = \ln \tau_{od} - N_{od}\phi^{N}\gamma M_d - (1 - N_{od})\,\phi^{\cancel{N}}\gamma\,(1 + \alpha_d)\,M_d - \delta N_{od}, \tag{2}$$

where N_{od} is a neighbor dummy, $\gamma > 0$ is a parameter that measures the extent to which, on average, the mine-related transport infrastructure is usable by other trades as well, M_d is defined as $\ln(1 + m_d)$, where m_d is the number of active mines in d, and $\delta > 0$ is a parameter that allows for the fact that transport costs may be lower between neighboring countries 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 some non-neighboring o_i when d has no mines (that is, there is no point M). The second and third terms in the above expressions capture the positive effect that the mine-related infrastructure is expected to have on d's import costs. Provided that d is a developing country - provided that $\phi^{\cancel{N}} > \phi^{N}$ - we expect this effect to be stronger for imports from $o_6, ..., o_n$ (for which $N_{od} = 0$) than for imports from $o_1, ..., o_5$ (for which $N_{od} = 1$). Furthermore, we expect this difference to be larger, the more d's mine-to-coast infrastructure happen to overlap with the location of its consumers (the larger is α_d).[11]

Next, consider a world in which there are also landlocked countries, and consider the im-

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[11] Which we later construct on the basis of the relative location of cities, ports, and mines.

pact of mine-related transport infrastructure on a landlocked destination country. This case is represented in Panel II of Figure 4. As for the case of a coastal d, we expect that, if d is a developing country, its mine-related infrastructure will be more likely to connect M to P than to a neighboring country. From a landlocked d, however, P can only be reached by first passing through a *transit* neighbor such as o_3. It follows that, for a landlocked d, we still expect the mine-related transport infrastructure to be more likely to reduce transport costs on imports from $o_6, ..., o_n$ than from non-transit neighbors such as o_1, o_2, o_4 or o_5. However the two probabilities should be roughly the same for $o_6, ..., o_n$ and d's transit neighbor, o_3.

To account for the existence of landlocked destination countries, we modify equation (2) as follows:

$$\begin{aligned}\ln \widetilde{\tau}_{od} = \ln \tau_{od} - N_{od}\phi^{N}\gamma M_d - \left(1 - N_{od}\right)\phi^{\not N}\gamma\left(1+\alpha_d\right)M_d - \delta N_{od} \\ - N_{od}T_{od}L_d\gamma\left(\phi^{\not N} - \phi^{N}\right)M_d - N_{od}T_{od}L_d\gamma\phi^{\not N}\alpha_d M_d - \zeta T_{od},\end{aligned} \tag{3}$$

where T_{od} is a dummy that takes value 1 if and only if o_i and d are in a transit relation, L_d is a landlocked dummy for the destination country, and $\zeta > 0$ is a parameter that captures the fact that transport costs may be lower between countries in a transit relation, for reason that have nothing to do with mine-related infrastructure. To interpret equation (3), consider how the second row modifies the expression of transport costs for a landlocked d ($L_d = 1$). Basically, we still expect the effect of mine-related infrastructure to be stronger for imports from $o_6, ..., o_n$ than from o_1, o_2, o_4 and o_5 (for which $N_{od} = 1$, $T_{od} = 0$), but not from o_3 (for which $N_{od} = T_{od} = 1$), where the marginal effect of M_d is the same as in the case of $o_6, ..., o_n$ ($(1 + \alpha_d)M_d$).

Re-arranging equation (3) yields:

$$
\begin{aligned}
\ln \widetilde{\tau}_{od} = \ln \tau_{od} - \phi^{\not N} \gamma \left(1+\alpha_d\right) M_d + \\
+ \left(\phi^{\not N} - \phi^{N}\right) \gamma M_d N_{od} + \phi^{\not N} \gamma M_d N_{od} \alpha_d - \delta N_{od} - \\
- N_{od} T_{od} L_d \left(\phi^{\not N} - \phi^{N}\right) \gamma M_d - N_{od} T_{od} L_d \gamma \phi^{\not N} \alpha_d M_d - \zeta N_{od} T_{od}
\end{aligned}
\tag{4}
$$

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

$$
\begin{aligned}
\ln \mathrm{imp}_{od} = k - \ln \tau_{od} + a_o + a_d + \\
+ \beta_1 N_{od} M_d + \beta_2 N_{od} M_d \alpha_d + \beta_3 N_{od} + \\
+ \beta_4 N_{od} T_{od} L_d M_d + \beta_5 N_{od} T_{od} L_d M_d \alpha_d + \beta_6 N_{od} T_{od} + v_{od},
\end{aligned}
\tag{5}
$$

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 (5) is our main theoretical equation. The variables contained in the first row of equation (5), as well as N_{od} and T_{od}, are standard gravity variables, and we expect $\beta_3, \beta_6 > 0$: neighbors trade more with each other, and that effect is stronger for neighbors that are also in a transit relation.

Our coefficients of interest are β_1, β_2, β_4, β_5. Our hypothesis implies that, if we run (5) for developing destination countries, it should be $\beta_1, \beta_2 < 0$ as long as the mine-related transport infrastructure is such to be physically usable by other trades as well (e.g. roads or railways, for which $\gamma > 0$). This is because a larger number of mines is associated with a better stock of mine-related infrastructure, which in developing countries is disproportionately likely to have a mine-to-coast trajectory. This disproportionately reduces the cost of importing goods from overseas countries, penalizing imports from neighbors ($\beta_1 < 0$). This trade re-direction effect is stronger, the more the mine-to-coast infrastructure overlaps with the route naturally used by domestic consumers to import from overseas countries ($\beta_2 < 0$). To run (5) for developed destination countries, or for the case in which the mine-related transport infrastructure cannot be possible used by other trades (e.g. pipelines, for which $\gamma = 0$), should instead yield $\beta_1 = \beta_2 = 0$. Our hypothesis also implies that, if and only if $\beta_1, \beta_2 < 0$, we should also find that $\beta_4, \beta_5 > 0$: in the case of a landlocked destination country importing from its transit neighbor, the trade re-direction effect of the mine-to-coast transport infrastructure should be reduced (if not completely offset) by the fact that this infrastructure will have to cut through the transit neighbor to reach the coast.

4 The impact of the location of mines on import routes

In the previous section, we have hypothesized that the mine-related infrastructure of a developing destination country is disproportionately likely to have a mine-to-coast trajectory, and may thus reduce import costs from overseas more than from neighbors. We now construct the mine impact index $\alpha \in [0, 1]$, measuring the extent to which the mine-to-coast infrastructure overlaps with the location of d's consumers, and thus actually contributes to reducing their imports costs from overseas. 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. The index offers a stylized interpretation of all potentially relevant geography, but this provides in our view the simplest sufficient approximation without having to resort to a full cost-benefit analysis of all possible routes and transport modes.

Consider a generic destination country d. Denote by C the geographical center point of cities, by M that of mines, and by P the country's main container port. Imagine to draw a line connecting C to P. A representation is provided in either panels of Figure 5. Next, draw the perpendicular dropping from M to the CP segment, and call I the point where the two lines intersect (Figure 5, panel I). Alternatively, if the perpendicular falls outside the segment CP, connect point M to point C (Figure 5, panel II). Finally, call S the closest coastal point to M.[12] Our proposed index is:

$$\begin{aligned} \alpha_d &= 0 \quad \text{if } \pi_d \text{ below average} \\ \alpha_d &= 1 \quad \text{if } \pi_d \text{ above average,} \end{aligned} \tag{6}$$

where:

$$\pi_d = \Pr\{\text{mines use P}\} * \Pr\{\text{mines use CP}\} * \text{share of CP used by mines,} \tag{7}$$

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

and where:

$$\Pr\{\text{mines use P}\} = \begin{cases} \frac{MS+1}{MP+1} & \text{if} \quad MS < MP \\ 1 & \text{if} \quad MS > MP \end{cases} \tag{8}$$

$$\Pr\{\text{mines use CP}\} = \begin{cases} \frac{MP+1}{MI+IP+1} & \text{if} \quad IP < CP \\ \frac{MP+1}{MC+CP+1} & \text{if} \quad IP > CP \end{cases} \tag{9}$$

$$\text{share of CP used by mines} = \begin{cases} \frac{IP+1}{CP+1} & \text{if} \quad IP < CP \\ 1 & \text{if} \quad IP > CP. \end{cases} \tag{10}$$

Equations (6)-(10) suggests that our mine impact index is a discrete version of a continuous mine-impact index index π_d. The latter is the product of three distinct terms. The first term is the probability that the mines use P to export their products, as opposed to the ideal, purpose-built port. Because P is the country's main container port, it is logical to expect that a large proportion of the country's overseas imports will be shipped through this port. Thus, a logical prerequisite for the mine-to-coast infrastructure to reduce transport costs for overseas imports is that such infrastructure converges to P. We proxy for the probability that this happens through the expression in equation (8), whose logic is explained in either panel of Figure 5.[13] Basically, mine-owners face a choice between exporting the resources through P, or establishing a purpose-built port somewhere else along the country's coast. We assume that the ideal location for such a port is S, that is the closest coastal point to M. Mine-owners only base their choice on the relative distance of P and S: the closer is P relative to S, the higher is the probability that they choose P. At the two extremes, if M is on the coast ($M = S$) and P is infinitely far, mine-owners

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[13] Notice that, as required of a probability, this expression takes value between 0 and 1.

always chooe S; if P is actually the closest coastal point to M ($P = S$), mine-owners always choose P.

The second term is the probability that the mines use a route overlapping with CP to reach P, as opposed to a more direct route. Since CP is the most direct route between the cities and P, it is logical to expect that a large proportion of the country's overseas imports will be channelled through this route. Thus, a pre-requisite for the mine-to-coast infrastructure to reduce transport costs for overseas imports is that such infrastructures overlaps with CP. We proxy for the probability that this happens by the expression in equation (9), whose logic is also illustrated in Figure 5. Having decided to ship their resources through P, mine-owners face the choice of whether to use, at least partially, the connection CP, or rather use a more direct route such as MP. As for the choice between P and S, mine-owners make a distance-based decision. However, we now need to distinguish two cases. When M is located as in the first panel of Figure 5, mine-owners compare the direct route MP to a route that joins CP on its closest point (segment CI) and then continues along a portion of CP to the port (segment IP). The first row of equation (9) captures the outcome of the mine-owners' choice in this case. The smaller is $MI+IP$ relative to MP, the higher is the probability that mine-owners carry the resources to P using, at least in part, CP. At the two extremes, if M is located on CP ($MI = 0$, $IP = MP$), mine owners always use CP. If $CI = IP$, mine-owners use CP with a lower probability $\frac{\sqrt{2}*IP+1}{2*IP+1}$.[14]

The case when M is located as in the second panel of Figure 5 is treated very similarly, except that mine-owners now compare the direct route MP to a route that joins MP at point M (segment MC) and then continues along the whole of CP to the port. The second row

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[14] Thus, the probability that mine-owners use CP is defined between $\frac{\sqrt{2}*IP+1}{2*IP+1}$ and 1.

of equation (9) captures the fact that the smaller is $MC + CP$ relative to MP, the higher the probability that mine-owners use CP. As in the previous case, this probability is defined between 1 and $\frac{\sqrt{2}*IP+1}{2*IP+1}$.

Finally, for a given probability that the mines use port P to ship their resources, and reach it through CP, the third term in equation (7) captures the extent to which the mine-related infrastructure will actually improve CP. We assume such impact to be proportional to the share of CP that the mine-related infrastructure actually overlaps with. Thus, when M is located as in the first panel of Figure (5), the impact of the mine-related infrastructure is larger, the larger is IP relative to CP (and ranges from 0 to 1 as I moves from P to C). When M is located as in the second panel of Figure (5), the impact of the mine related infrastructure is always maximum (that is, 1).

Having constructed the index π_d, we then take a discrete version of it and use it as a our mine impact index (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, for example because it omits some other relevant feature of geography or because of variation in the modes of transport of different goods in different countries. However, without other priors on how to measure the true impact of the location of mines on city-port infrastructure and total imports, we choose to split the sample into two groups: those with a 'high' score, and those with a 'low' score of π_d. The index α_d is then attributed value 1 when π_d is above the average, value 0 when it is below. It is unlikely that these two groups would change composition much by choosing a different definition of π_d. For example, we indeed find that the results based on the indicator are robust to using different metrics of point C.

We conclude this section by considering the case of landlocked countries as illustrated in Figure 6. Denote by C^T the geographical center point of cities in the transit country, and by P^T that country's main container port. Then, we construct the index just as indicated in (6)-(10), except that we substitute P with P^T and CP with CC^TP^T. The latter is a hypothetical line connecting C to P through C^T.

5 Data

To estimate the effect of mine-related transport infrastructure on trade we need bilateral trade flows between as many countries as possible, as well as a measure of mine-related transport 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.[15] We measure the value of trade at the importing country and use the 2006 cross-section, which should cover more countries (particularly for Africa) and be of better quality than historical data. 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.

Our ideal explanatory variable would be a measure of mine-related transport infrastructure that takes into account not only the amount of infrastructure, but also its quality and direction (that is, whether it has a mine-to-coast trajectory or not). Although data exists on the total

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

length of the paved road and rail network in many countries, we cannot observe the quality and direction of mine-related infrastructure directly. As explained in the previous section, we will therefore use the number of active mines as a proxy for the amount and quality of mine-related infrastructure. We will work under the identifying assumption that, in developing countries (and in these only), mines tend to have a mine-to-coast trajectory, and that the effect of this on transport costs will also depend on the location of mines, and on the type of resource exported.

For us to be able to estimate equation (5), we first of all need data on the number of active mines in each country (M_d). To calculate the index α_d, we also need data on the geographical midpoint of mines in each country (point M in Figures 5 and 6), the urban population weighted geographical midpoint of main cities (point C), the location of the country's main container port (point P), and the point on the shoreline nearest to point M (point S). Finally, we need data on the specific neighbor that each landlocked country uses for transit (T_{od}).

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).[16] 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, 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 contains 305,832

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

records, but after extensive cleaning we are left with 20,900 mines.[17] Within this selection of mines 66% are located in the US, while the remaining 7122 mines cover 129 countries.[18] The MRDS data gives us both the number of mines in each country (M_d) and their location, allowing us to calculate point M.[19]

To calculate point C, we used data on cities from the UN's "World Urbanization Prospects" database of urban agglomerations with at least 750,000 inhabitants in 2010, to which we add hand collected city coordinates. We choose the earliest available figure for population (1950), because current population sizes may have been influenced by infrastructure itself. To identify point P, 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 for all countries with at least one port included in the ranking. For countries that are not included in the AAPA ranking, we use, when possible, 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

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[17] Our empirical strategy requires that we focus on mines that were active in 2006 (or ceased activity not too long before then, since for these mine-related infrastructure will still be in place), and for whom we know the location. We thus 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 their country's mainland.

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

[19] Full details on how we calculated point M for each country, given the location of the country's mine, is provided in the online technical appendix.

the country's capital.[20] Finally, for countries that are neither included in the AAPA ranking nor reached by Maersk Line, we identify the main commercial port by conducting a series of internet searches.[21] We coded as "port co-ordinates" those of the port's nearest city, which we got from the World Urbanization Prospects database, and, for smaller cities, from Wikipedia/GeoHack.

The Maersk data also allows to identify, per each landlocked country, the specific neighbor that this country uses for transit (T_{od}).

Table 3 in Appendix D reports the top 40 countries according to the number of mines in combination with the mine impact index π_d.[22] 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 extent to which the mine-related infrastructure is expected to reduce the cost of importing from overseas (measured by π_d). 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 therefore 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 4 shows, for major groups of countries, summary statistics on the number of mines

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[20] Maersk Line has the largest market share (18%) according to http://www.shippingcontainertrader.com/facts.shtml.

[21] 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.

[22] The top three products are gold, sand & gravel, and copper. Other heavy ores such as iron and aluminium (bauxite) which are usually transported by rail rank seventh and eighth and each represent 3% of all mines.

and the mine impact index, both in its continuous and discrete version (π_d and α_d). 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.

Finally, we always control for a broad set of standard multilateral resistance terms, taken from Head *et al.* (2010). These are *ln distance*, the log of distance between countries; *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 and members of the 'Asia−Caribbean−Pacific' preferential tariff agreement for former European colonies.

6 Results

This section is organized in four parts. In section 6.1, we present our baseline specification. This is a simplified version of equation (5), where we show that countries with more mines trade proportionately less with neighbors. In the next three sections, we present evidence that such trade re-direction effect of mines is due to mine-to-coast infrastructure. In sections 6.2 and 6.3, we progressively enrich our specification as suggested by equation (5). In particular, in section 6.2 we look at whether the trade re-direction effect is affected by the exogenous location of mines. In section 6.3, we look at whether the trade re-direction effect is different for landlocked countries importing from their transit neighbor. We conclude in section 6.4, where we return to our baseline specification and conduct a falsification exercise by comparing the trade re-direction effect of mines versus oil fields.

6.1 The trade re-direction effect of mines

Our baseline specification is a simplified version of equation (5), where we assume $\beta_2 = \beta_4 = \beta_5 = \beta_6 = 0$. Our results are reported in Table 5. 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.[23] For our main variables of interest, NM_d and N,[24] we find that a country imports twice as much from its neighbors than from its non-neighbors (1.068*100%), but this effect is smaller, the larger is the number of mines in the destination country.[25] Figure 7 summarizes this relationship. The figure plots the marginal effect

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[23] An indicator for ACP treatment of imports into the European Union (or preceding associations), which also includes many African former colonies, affects trade negatively. Head *et al.* (2010) found that the sign of this variable is very sensitive to the specification used. We find that it does increase trade for African countries (column e).

[24] To simplify the notation, we drop the "*od*" subscripts from pair-specific variables from now on.

[25] 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

of being neighbors on trade, as a function of the number of mines in the destination country. As we increase the number of mines, the marginal effect of N decreases. Countries with 33 mines or more ($\exp 3.5$) (i.e. those listed in Table 1) do *not* import significantly more from their neighbors than from any other country. In the extreme case of the US, which has the largest number of mines in the sample, we even find a negative marginal effect of N. Our results hold if we exclude this extreme case (column b of Table 5). Since countries with a larger number of active mines will have a larger and better stock of mine-related infrastructure, this is *prima facie* evidence in favor of our hypothesis - that mine-related infrastructure has a mine-to-coast trajectory, and thus re-directs trade towards overseas countries and away from regional trading partner.

If our hypothesis is right, we should also observe that mines only have a trade re-direction effect in developing countries. This is because mine-related infrastructure will be much less likely to have a mine-to-coast trajectory in developed countries. When we split the sample in OECD and non-OECD destinations (columns c and d), we find precisely this result. OECD destinations do not import significantly more from neighbors, *and* this does not depend on the number of mines. 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. On the contrary, we do find a trade re-direction effect for non-OECD and African destinations, although this is not significant for the *average* country in Africa. Because the interaction is between a dummy and a continuous variable, however, the coefficient, its variance,

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effect of the index interaction in the African sample as before. The negative effect is no longer significant for the average non-OECD country, 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 therefore our preferred dependent variable.

and the covariance between NM_d and N determine a range for which also the African countries do not import significantly more from neighbors. This occurs if they have more than about 20 mines.

Looking at the illustrative maps of infrastructure in Africa suggests that the trade re-direction relationship may depend explicitly on the position of mines relative to urban centers and existing trade routes. This will be examined next.

6.2 Does the location of mines matter?

We now enrich our baseline specification by including the mine impact index α_d. In terms of equation (5), we allow for $\beta_2 \neq 0$. The mine impact index is constructed using the geographical location of mines. It measures the extent to which the hypothetical mine-to-coast infrastructure cuts through a country's cities, and thus its potential to re-direct trade. Thus, the index provides an exogenous source of variation that we can use to test for our hypothesis that mine-to-coast infrastructure is responsible for the trade re-direction effect documented in section 6.1. In Table 6, we add the triple interaction $NM_d\alpha_d$ to our baseline specification.[26] To interpret the coefficient on the interactions, we proceed in two steps. First, we calculate the marginal effect of M_d on imports from neighbors, and look at how this depends on the value of the index, α_d. Second, we calculate the marginal effect of N on imports for a range of M_d, and look at how this second marginal effect depends on the value of the index.

By setting $N = 1$, we initially focus on imports from neighbors. Due to the triple interaction between N, M_d and α_d, the size of the marginal effect of M_d, and its significance, will depend

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[26] We do not report controls from now on, although these are always included in the regression.

on the mine impact index α_d.[27] Re-writing equation (5) with $\beta_3 = \beta_4 = \beta_5 = 0$ yields:

$$\begin{aligned} \ln \text{imp}_{od} = k - \ln \tau_{od} + a_o + a_d + \\ + \beta_1 N_{od} M_d + \beta_2 N_{od} M_d \alpha_d + \beta_3 N_{od} + \upsilon_{od}. \end{aligned} \tag{11}$$

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

$$\left.\frac{\partial \ln \text{imp}_{od}}{\partial M_d}\right|_{N_{od}=1} = \widehat{\beta}_1 + \widehat{\beta}_2 \alpha_d \tag{12}$$

And its standard error follows as:

$$s.e. = \sqrt{\text{Var}\widehat{\beta}_1 + \alpha_d^2 \text{Var}\widehat{\beta}_2 + 2\alpha_d \text{Cov}(\widehat{\beta}_1, \widehat{\beta}_2)} \tag{13}$$

Figures 8, 9, and 10 display the marginal effect of M_d on imports from neighbors for a sample of all, non-OECD and African destinations respectively, with dashed 95% confidence bands. A $*$ denotes values significant at 90% confidence. Whereas in the world sample the index α_d does

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[27] 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 11, 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. We consider this to be unrealistic. 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.

not change the marginal effect of M_d (reflecting the small β_2 coefficient in Table 6), we find that for non-OECD destinations and African destinations, the marginal effect is only significant and negative for countries with a high value of the index ($\alpha_d = 1$). In other words, a larger number of mines re-direct trade away from neighbors only in countries where the hypothetical mine-to-coast transport infrastructure has a high potential for re-directing trade. This implies that, for example, remote Chilean mines (which have a below-average π_d score of 0.06) have much less influence on the direction of trade than South African mines do (which have an above-average score of 0.75), since Chilean mines are much farther from import routes.

In figures 11 and 12 we take a different look at the same regressions. We now take the derivative of $\ln \text{imp}$ with respect to N (as we did for figure 7) and calculate this marginal effect as it depends on M_d (with asterisks now denoting 95% confidence). However, because of the interaction with α_d, we can now draw two different lines, one for $\alpha_d = 0$ and one for $\alpha_d = 1$. For a zero score of M_d 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. Figure 11 suggests that the trade re-direction effect is stronger (given by a steeper line) for countries where the mine-to-coast infrastructure has a high potential for re-directing trade ($\alpha_d = 1$). 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 if $\alpha_d = 0$. But if $\alpha_d = 1$, we find that also countries with more than 27 mines ($= \exp 3.3$) do not trade more with neighbors. The reason is that in these countries, the mines are positioned in such way that the associated mine-to-coast transport infrastructure improves existing trade routes between cities and ports, causing a large decline in trade costs with overseas countries, relative to trade costs with neighbors.

In figure 12 we find a different pattern for African destinations. A relatively small number of 6 mines ($= \exp 1.8$) causes the marginal effect of N 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.

6.3 Landlocked countries importing from transit neighbors

Next, we enrich our baseline specification by looking at the effect of mines on the direction of trade in landlocked countries. While we would ideally like to estimate equation (5) in full, the number of landlocked countries is too small to provide us with sufficient variation in the mine impact index, α_d.[28] We thus return to a more parsimonious specification where $\beta_2 = 0$, and allow for $\beta_4, \beta_6 \neq 0$ in this section.

If mine-to-coast infrastructure is the mechanism behind the trade re-direction effect of mines, then this effect should disappear for landlocked countries importing from their *transit* neighbor. This is because for these specific neighbors, a larger stock of mine-to-coast infrastructure should be *good* news, not bad news. For example, Uganda's railway crosses Kenya to reach the sea: but then the railway should decrease the cost of importing from Kenya, as well as from overseas countries. Thus, landlocked countries with a larger number of mines should still import proportionately less from "normal" neighbors, but they should import proportionately more from

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[28] In addition to the fact that not many countries are landlocked, we don't have information for the mine impact index for a few of them.

transit neighbors. Since it is hard to think of an alternative story for why this should be true, we believe this would be strong evidence in favor of our hypothesis.

In Table 7 we add the two interactions NTL_dM_d and NT to our baseline specification. We define T as a dummy equal to one if two neighboring countries are in a transit relation, and by L_d a destination landlocked dummy. Thus, if $NTL_d = 1$, we are looking at the case of a landlocked destination country importing from its transit neighbor. As before, we interpret the coefficients on the two interactions graphically. Figures 13 and 14 summarize the findings of Table 7 for a sample of non-OECD and African destinations respectively. The solid line in these figures represents the marginal effect of N on trade, as in Figure 7, but for destination countries that are not both landlocked and in a transit relationship with the origin country. Again, we find that a higher number of mines re-direct trade away from neighbors, to the extent that the positive marginal effect of neighbor may disappear for a high enough number of mines. 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 neighbor. The difference between the solid and the dashed line is remarkable for non-OECD destinations, but is even starker for African destinations.

Comparing Tables 5 and 7 we see that the value of M_d for which the marginal effect of N becomes insignificant drops for all samples, once we take into account that some neighbors are transit neighbors and therefore benefit from the destination country having a high number of mines.

6.4 Mines versus oil fields

In the previous three sections, we have used the number of mines as a proxy for mine-to-coast infrastructure. A potential problem with this proxy is that resource exports could also have asymmetric income effects on trade, over and above the symmetric income effects which are controlled for by origin and destination dummies (such as an increase in GDP). For example, if developing countries spend their resource income on luxury goods which they purchase on world markets rather than on neighboring markets, this would lead to a trade re-direction effect very similar to the one we find. Alternatively, we could be picking up the fact that countries with more mines import lots of mine-related machinery, which they also tend to purchase on world markets. While this alternative channel could not explain why the *location* of mines matter alongside their number (as shown in section 6.2 and 6.3), we use this section to further address this issue.

A natural falsification exercise is to investigate whether oil and gas fields have a similar trade re-direction effect to that of mines. While the income channel should still be at play for oil and gas fields, the infrastructure channel should not. To see why, recall that the infrastructure channel relies on the assumption that the mine-to-coast infrastructure can be used not only to export the minerals, but also to import a broad set of commodities. But while metals and other non-hydrocarbon minerals are mostly transported through roads and railways, oil and gas are mostly transported through pipelines. Clearly, the former may also be used for imports, while the latter cannot.[29] Thus, if the trade re-direction effect is due to income, it should be there for

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[29] Pipelines may have an effect through the construction of maintenance and access roads, but we expect this to be small.

both mines and oil and gas fields. If it is due to mine-to-coast infrastructure, on the contrary, it should be there for mines only.

We extend our regressions in section 6.2 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.

Results are 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 effect 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.[30] We conclude from this falsification exercise that number of mines leads to a smaller

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[30] 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

trade re-direction effect, and that the main channel is mine-to-coast infrastructure rather than any asymmetric income effects.

We provide various robustness checks in Appendix E (available on line). In particular, we try to control for the size of countries, run a two-step regression to estimate both the external and internal margin of trade, and re-run our regressions after dropping all countries that are reported as having zero mines. Our main results turn out to be robust to all of these alternative specifications.

7 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 mine-to-coast infrastructure, this does automatically imply that such infrastructure must have a negative welfare effect.

First, our results do now allow us to rule out that, thanks to mine-to-coast infrastructure, countries with more mines import more from *all* countries. This is because all of our specifications include destination fixed effects, which absorb any effect that the infrastructure may have on average imports. Thus, even if mine-to-coast infrastructure results in a reduction in transport costs that is biased in favor of overseas countries, it may still reduce transport costs on imports from neighbors as well. For example, some neighboring countries may also be able to take advantage of a line connecting the interior to a port, if some of their exports are best routed through the latter.[31]

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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.

[31] For example, country o_1 in figure 4, panel I, could channel its export to d through port P, and thus also

Next, even if the mine-to-coast infrastructure reduced imports from neighbors in absolute terms, this needs not be bad for the country where the infrastructure is built. The opening up of new mines will typically relax the budget constraint faced by the government, particularly in cash-starved developing countries. Thus, the mine-to-coast infrastructure may simply add to the country's pre-existing transport network, implying a reduction in overall transport costs. Furthermore, even if the mine-to-coast infrastructure bites into the government's infrastructure budget, we cannot rule out that its construction is welfare maximizing, given the importance of resource exports for developing countries.

The fact that we cannot draw precise welfare implications from our results, however, does not imply that such results are not important from a welfare perspective. There are several reasons to believe that the mine-to-coast infrastructure may have a negative welfare effect, both on neighboring countries and on the country where it is built.

For the former, any positive welfare implication must come from the possibility of lower transport costs, if they also use the mine-to-coast infrastructure to trade with the country where it is built. However this route may not be economical, or even accessible, to many of them, for which the welfare impact of mine-to-coast infrastructure would then have to be negative.[32] Furthermore, even neighbors that use the mine-to-coast infrastructure may, as a result of such infrastructure, face much tougher competition from overseas countries. Since the latter may include highly efficient industrialized countries, such an enhanced level of competition may be very detrimental for a burgeoning regional industry.

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benefit from a better connection between P and M.

[32] In the example used in footnote 31, the overland connection between o_1 and d may still be the cheapest *even after* the establishment of a better connection between P and M. In that case, the improved connection between P and M would play to o_1's disadvantage.

Cheaper imports from overseas countries may also be detrimental for the domestic industry of the country where the mine-to-coast infrastructure is built, since this will face both tougher competition at home, and no additional benefit in terms of expanded regional markets. This effect should be bigger, the more the mine-to-coast infrastructure bites into the government's infrastructure budget, and is thus associated with a deterioration in regional infrastructure.

Ultimately, the importance of these effects is likely to depend on the kind of government optimization that has led to the construction of the mine-to-coast infrastructure. There is more than one reason to suspect that such optimization may not be welfare-maximizing. "Contemporary" reasons include, first, the fact that the trade re-direction effect of mine-to-coast infrastructure may not be immediately evident to governments, or that these may have their own political agenda that favors the realization of quick profit from the export of natural resources. Second, there may be difficult co-ordination issues between countries in the construction of regional infrastructure, whereas the mine-to-coast infrastructure faces fewer problems of this sort.

Even more important, however, may be the historical reasons underlying the existence of the mine-to-coast infrastructure. Specifically, much of this infrastructure was built in colonial times, when the maximization of the welfare of colonies was typically not their government's primary goal. Although our results are not conclusive evidence in favor of dependency theories, they are consistent with the argument that colonial investment in interior-to-coast transport infrastructure has had a long-run adverse effect on the regional integration of developing countries. It is an important task for future research to try and establish the causal effect of this and other related colonial policies on contemporary economic performance and welfare.

8 Conclusions

An old but influential critique of colonialism holds colonial policies responsible for bringing long-lasting damage to the regional trade of former colonies. Interior-to-coast transport infrastructure is singled out as one of these policies. By biasing the structure of transport costs in favor of overseas countries, it is claimed, this type of infrastructure disproportionately favored trade with overseas countries, to the detriment of regional trade.

We have presented first econometric evidence that current mine-to-coast infrastructure - much of which was inherited from colonial times - matters for the current pattern of trade of developing countries, and can help explain their low level of regional integration. Developing countries with a larger number of mines import proportionately less from regional trade partners. Three separate facts suggest that this trade re-direction effect is likely to be due to mine-to-coast infrastructure. First, the effect is stronger when the location of mines is such that the associated mine-to-coast infrastructure has a high potential for re-directing trade. Second, the trade re-direction effect is inverted for landlocked countries importing from their transit neighbor. This is consistent with the fact that the mine-to-coast infrastructure will have to cut through the transit neighbor, and will thus bias transport costs not against it, but in its favor. Finally, the trade re-direction effect disappears if we use the number of oil and gas fields instead of mines. Arguably, this is because oil and gas, differently from other mineral resources, are transported through pipelines, which do not have the capacity to bias a country's general transport costs.

Although it is hard to draw precise welfare implications from our results, there are a number of well-known reasons why little regional integration may be detrimental to the domestic industry of the country where the interior-to-coast infrastructure is built, and of its neighbors. More in general, our results lend support to the idea that colonial investment in infrastructure - which was clearly not undertaken with the maximization of colonial welfare as a primary goal - has had a long-run effect on contemporary trade patterns. We believe this may have important implications for the debate on the economic legacy of colonialism.

One important related question is why the interior-to-coast infrastructure persisted over time, if it was inefficient. We believe there are at least three complementary explanations. The first is that there are very high fixed costs to producing new transport infrastructure, which may make it hard to re-orient the structure of a country's transport network. In addition, the construction of regional transport infrastructure may involve difficult coordination issues among neighboring countries. The second explanation is based on institutions. According to Acemoglu and Robinson (2012), colonizers mostly left behind bad political institutions, whereby a ruling elite does not have an incentive to provide the good economic institutions that would spur sustained economic growth. A balanced transport network may well be among these under-provided institutions, particularly given that mine-to-coast transport infrastructure will already serve very well the elite's revenue-collecting needs. Finally, mine-to-coast transport infrastructure may be favored by overseas donors, whose trade it disproportionately favors. This may be particularly true in the case of recent Chinese aid to Africa, which is typically tied to the negotiations of trade deals, and paid out in the form of large infrastructural projects. We believe these hypotheses offer fascinating avenues for future research.

References

[1] Acemoglu Daron, Simon Johnson and James A. Robinson (2001). "The colonial origins of comparative development: an empirical investigation", *American Economic Review*, Vol. 91, No. 1369-1401.

[2] Acemoglu, Daron and James A. Robinson (2012). *Why Nations Fail - The Origins of Power, Prosperity and Poverty*, London, Profile.

[3] Amin, Samir (1972). "Underdevelopment and Development in Black Africa - Origins and Contemporary Forms", in the *Journal of Modern African Studies*, Vol. 10, No. 4, pp. 503-524.

[4] Banerjee, Abhijit, Esther Duflo, and Nancy Qian (2012). "On the Road: Access to Transportation Infrastructure and Economic Growth in China", *NBER Working Papers*, No. 17897.

[5] Buys, Piet, Uwe Deichmann and David Wheeler (2006). "Road Network Upgrading and Overland Trade Expansion in Sub-Saharan Africa", *World Bank Policy Research Working Papers*, No. 4097, December 2006.

[6] Canning, David (1998). "A Database of World Infrastructure Stock, 1950-1995", in *World Bank Policy Research Working Papers*, No. 1929.

[7] Center for African Studies, University of Edinburgh (1969). *Proceedings of a Seminar Held in the Center of African Studies*, University of Edinburgh, 31st October and 1st November 1969.

[8] Collier, P. and Anthony J. Venables (2010). "Trade and Economic Performance: Does Africas Fragmentation Matter?", in Lin, Justin Yifu, and Boris Pleskovic (Eds.), *People, Politics and Globalization*, World Bank, 2009 ABCDE Conference.

[9] Djankov, S., R. La Porta, F. Lopez-de-Silanes, and A. Shleifer (2002). *The Regulation of Entry*, *Quarterly Journal of Economics*, Vol. 117, pp. 1-37.

[10] Donaldson, Dave (2012). "Railroads of the Raj: Estimating the Impact of Transportation Infrastructure", *mimeo*, MIT.

[11] Dos Santos, T. (1970). "The Structure of Dependence", *American Economic Review* 60(2), 231-236.

[12] Easterly, W. and R. Levine (1998). "Troubles with Neighbors: Africa's Problem, Africa's Opportunity", in the *Journal of African Economies* 7(1), 120-142.

[13] Faber, Benjamin (2012). "Trade Integration, Market Size, and Industrialization: Evidence from Chinas National Trunk Highway System", *mimeo*, LSE.

[14] Feyrer, J.D. and B. Sacerdote (2009). "Colonialism and modern income: islands as natural experiments", in *Review of Economics and Statistics*, Vol. 91, No. 2, pp. 245-262.

[15] Freund, B. (1998). *The Making of Contemporary Africa the Development of African Society Since 1800*, Basingstoke (UK), MacMillan Press.

[16] Halbouty, M.T., A. Meyerhoff, R.E. King, R.H. Dott, D. Klemme and T. Shabad, (1970). "World's Giant Oil and Gas Fields, Geologic Factors Affecting Their Formation, and Basin

Classification: Part I: Giant Oil and Gas Fields."in *AAPG Memoir 14: Geology of Giant Petroleum Fields*, pp. 502-528.

[17] Head, K., T. Mayer and J. Ries (2010). "The erosion of colonial trade linkages after independence", *Journal of International Economics*, Vol. 81, No. 1, pp. 1-14.

[18] Heckman, James J. (1979). "Sample Selection Bias as a Specification Error", in *Econometrica*, Vol. 47, No. 1, pp. 153-161.

[19] Helpman, E., M. Melitz and Y. Rubinstein (2008). "Estimating trade flows: trading partners and trade volumes", in *Quarterly Journal of Economics*, Vol. 123, No. 2, pp. 441-487.

[20] Horn, M.K. (2003) "Giant Fields 1868-2003 (CD-ROM)", in Halbouty, M.K., ed., *Giant Oil and Gas Fields of the Decade, 1990-1999*, Housto, AAPG Memoir 78.

[21] Huillery, E. (2009). "History Matters: The Long-Term Impact of Colonial Public Investments in French West Africa", A*merican Economic Journal: Applied Economics*, Vol. 1, No. 2, pp. 176-21.

[22] Iyer, L. (2010). "Direct versus Indirect Colonial Rule in India: Long-term Consequences", *The Review of Economics and Statistics*, Vol. 92, No. 4, pp. 693-713.

[23] Jedwab, Remi and Alexander Moradi (2012). "Colonial Investment and Long-Term Development in Africa: Evidence form Ghanaian Railroads", mimeo, LSE.

[24] Keller, Wolfgang and Carol H. Shiue (2008). "Institutions, Technology, and Trade", *NBER Working Papers*, No. 13913.

[25] Limao, Nuno and Antony A. Venables (2001). “Infrastructure, Geographical Disadvantage, Transport Costs, and Trade”, in *The World Bank Economic Review*, Vol. 15, No. 3, pp. 451-479.

[26] Michaels, Guy (2008). “The Effect of Trade on the Demand for Skill: Evidence from the Interstate Highway System”, *Review of Economics and Statistics*, Vol. 90, No. 4, pp. 683-701.

[27] Nunn N. (2008). “The long-term effects of Africas slave trades”, *Quarterly Journal of Econonics*, No. 123, pp. 139-176.

[28] Perdersen, P.O. (2001). “The Freight Transport and Logistical System of Ghana”, in *CDR Working Papers*, Copenhagen, Center for Development Research.

[29] van der Ploeg, F. (2011). “Natural Resources: Curse of Blessing?” in the *Journal of Economic Literature* 49(2), 366-420.

[30] Prebisch, R. (1950). *The Economic Development of Latin America and Its Principal Problems*. New York: United Nations.

[31] Roberts, M. and U. Deichmann (2009). “International Growth Spillovers, Geography and Infrastructure”, in *Policy Research Working Papers*, Washington, the World Bank.

[32] Rodney, W. (1982). *How Europe Underdeveloped Africa*, Washington DC, Howard University Press.

[33] Sachs, J.D., J.W. McArthur, G. Schmidt-Traub, M. Kruk, C. Bahadur, M. Faye and G. McCord (2004). “Ending Africas Poverty Trap”, in *Brookings Papers on Economic Activity* 2004(1), 117-226.

[34] Santos Silva, J. M. C. and Silvana Tenreyro (2006). "The Log of Gravity", in *Review of Economics and Statistics*, Vol. 88, No. 4, pp. 641-658.

[35] Singer, H. (1950). "The Distribution of Gains between Investing and Borrowing Countries", *American Economic Review*, Vol. 40, pp. 473-485.

[36] Taafe, E., R. Morrill and P. Gould (1963). "Transport Expansion in Underdeveloped Countries: A Comparative Analysis", in the *Geographical Review* 53(4), 503-529.

[37] Venables, A.J. (2003). "Winners and Losers from Regional Integration Agreements", in the *Economic Journal* 113, 747-761.

[38] Venables, A.J. (2009). "Economic Integration in Remote Resource-Rich Regions", in *OxCARRE Research Papers*, No. 22.

Appendices

A Maps

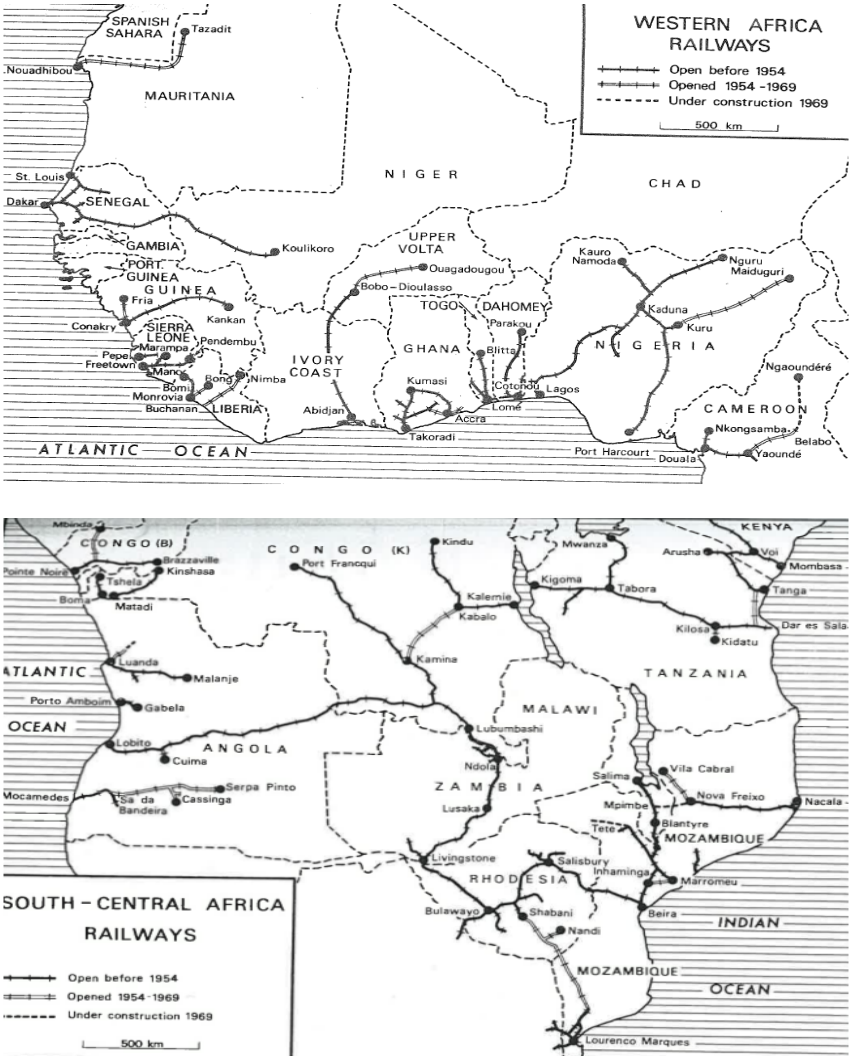
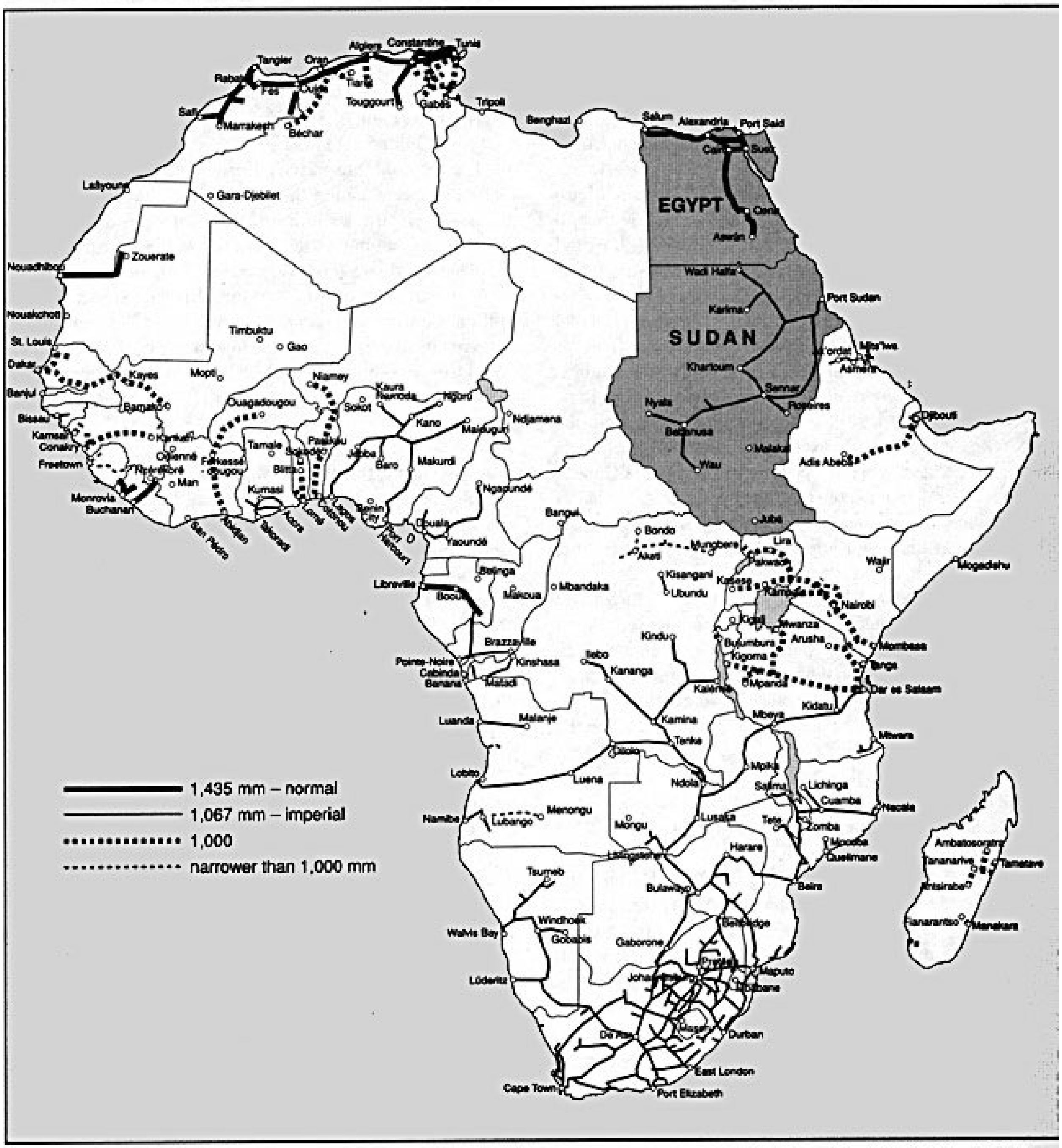


Figure 1: African Colonial Railways, 1960s. Source: Center of African Studies, University of Edinburgh (1969).

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 2: African railways, 1990s.

B Ghana: a case study

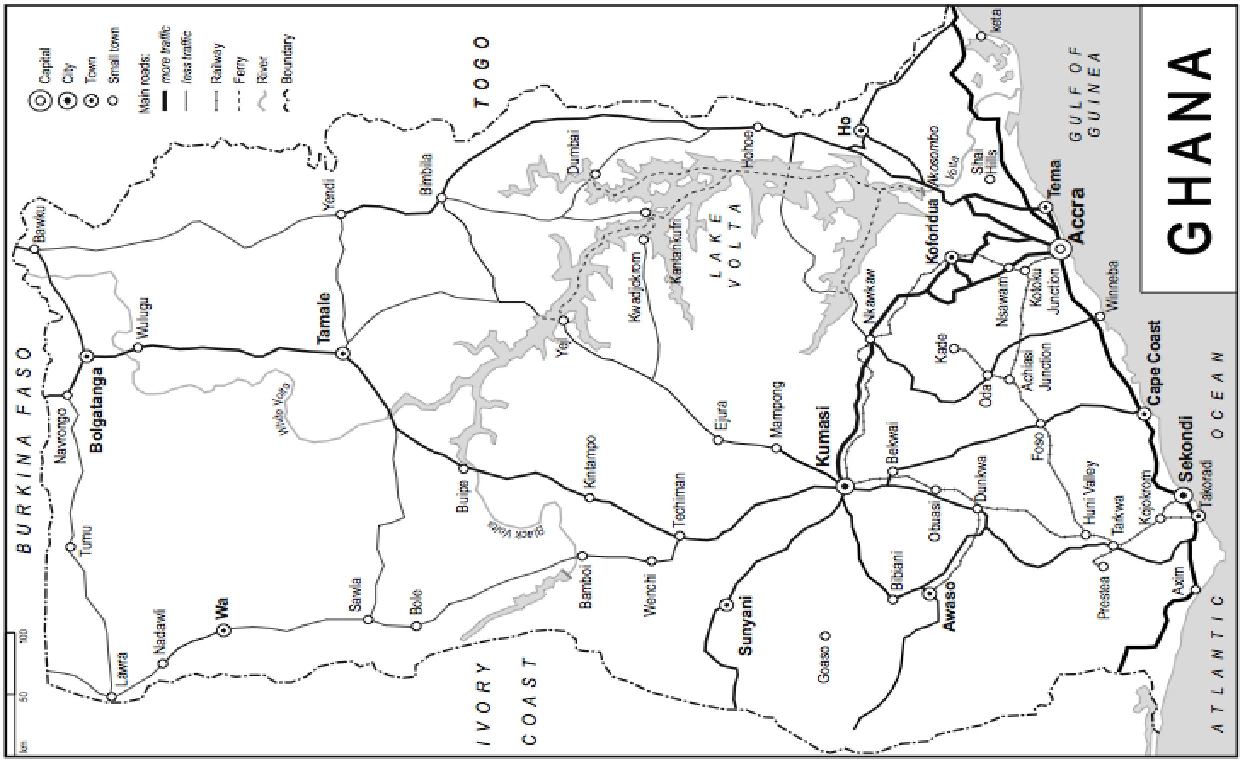


Figure 3: Ghana, transportation system, 2001. Source: Pedersen (2001).

Until the second half of 19th century, Ghana's transportation system[33] consisted of a network of narrow trails used for head carriage, and a large number of small ports in fierce competition with one another.[34] As the British established full control over Ghana in 1901, investments to upgrade the interior-to-coast infrastructure were rapidly undertaken. The need to establish military control over contested parts of the interior had primary importance in the specific case of Ghana,[35] but the wish to export mineral and agricultural resources was also very important.

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[33] This case study is based on Taafe et *al.* (1960) and Pedersen (2001).

[34] These ports, which belonged to different European colonizers, exported slaves, gold, and later also palm oil, rubber and timber.

[35] The region around Kumasi was contested between the British and the Ashanti, whereas parts of the North-East were contested between the British and the French.

The Western Railway connecting the port of Sekondi to the inland city of Kumasi was completed in 1904. Its main economic goal was to export gold from the mines around Tarkwa and cocoa from the area around Kumasi, and to import mining equipment and food for the growing local population. In 1944, it was extended westward, to tap the manganese and bauxite deposits of Awaso. Similarly, the Eastern Railway connecting the port of Accra to Kumasi (completed in 1923) and the Central Railway connecting the two lines (completed in 1956) had the primary economic goal of exporting cocoa, produced in the area to the North and North-West of Accra. As a result of the railways, Accra and Sekondi - with their newly-built port terminals at Takoradi (1928), and Tema (1962) - completely displaced the other smaller ports on the Ghanaian cost.

As the railways developed, so did the road network. In the South, the roads were initially feeder roads that worked for the railways. Later, trunk roads were constructed, that competed with the railways for essentially the same trade flows. Not surprisingly, most of the trunk roads had a trajectory that followed closely that of the railways. One exception was the road from Accra to the Eastern city of Hohoe, that was built to prevent the cocoa production of that region to be exported through the neighboring French port of Lome'. In the North, where it did not face competition from the railways, the road network developed much faster. Although the main rationale for the construction of the Kumasi-Tamale and Hohoe-Yendi trunk roads was political,[36] these roads also facilitated the transportation of food from the North to the mining and plantation economy of the South. From the 1950s onwards, the road network became the most important component of the Ghanaian transportation system.

After decolonization, the Ghanaian transportation system underwent a period of physical

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[36] The former was instrumental to establishing administrative control over Northern Ghana, whereas the latter was associated with the political desire to forge a link between Ghana and British Togoland.

deterioration and declining rail and road traffic. This reached its lowest point in 1983. After that year, the government and international donors started a road rehabilitation program that, by the late 1990s, brought the system back to the levels of efficiency of the early 1970s. Overall, the structure of the national transportation system underwent very little change between 1960 and 2000.

At the beginning of the 21st century, almost all of Ghanaian foreign trade is handled by the Takoradi and Tema ports, whereas very little trade is handled by the country's various overland entry points. The country's main exports - gold, bauxite, manganese, cocoa and timber[37] - are transported through the old colonial railways and roads from the interior to the sea. Ghana imports liquid and dry bulk commodities, but also containerized goods for a large overall value.[38] A large portion of these find its final destination in the Accra and Sekondi area, but a substantial portion is transported through the interior along the old colonial roads, after having been uploaded on trucks.[39]

In summary, Ghana is an example of a country where a rich endowment of mineral and agricultural resources resulted in a colonial system of transport infrastructure that displays a clear interior-to-coast pattern. Such system survived almost unchanged in the decades after independence, and still completely determines the direction followed by the country's foreign trade flows. Because of its interior-to-coast pattern, the Ghanaian transportation system is likely to bias the country's transport costs in favor of overseas trading partners, and to the detriment of regional trading partners. This, in turn, may have important consequences for the

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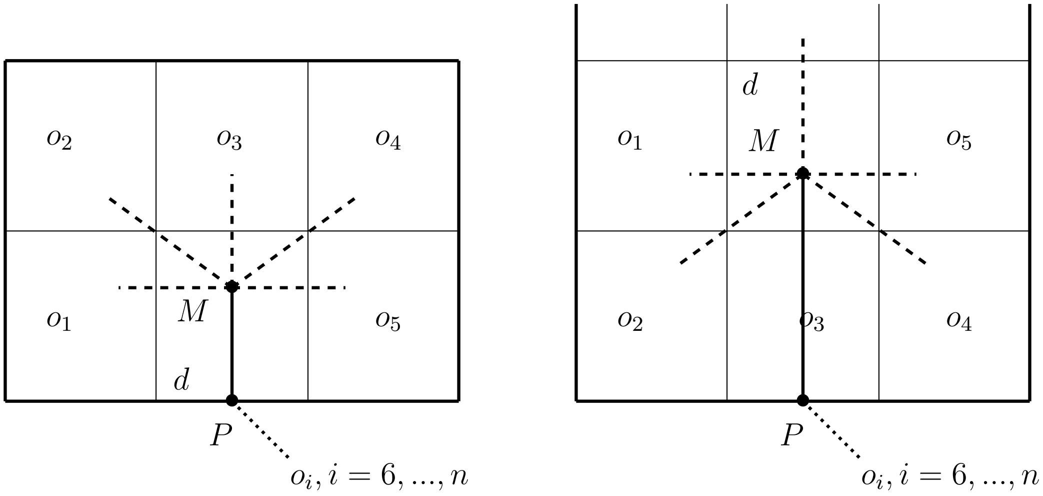
[37] In recent years, the export of offshore oil has become an important component of Ghanian trade.

[38] To avoid returning empty containers, cocoa and timber exports are also increasingly containerized

[39] Because of distortive custom regulations as well as a much higher volume of imports relative to exports, most manufactured goods do not travel overland on containers, but are loaded on trucks at the port of arrival.

possibility of economic integration in this region.

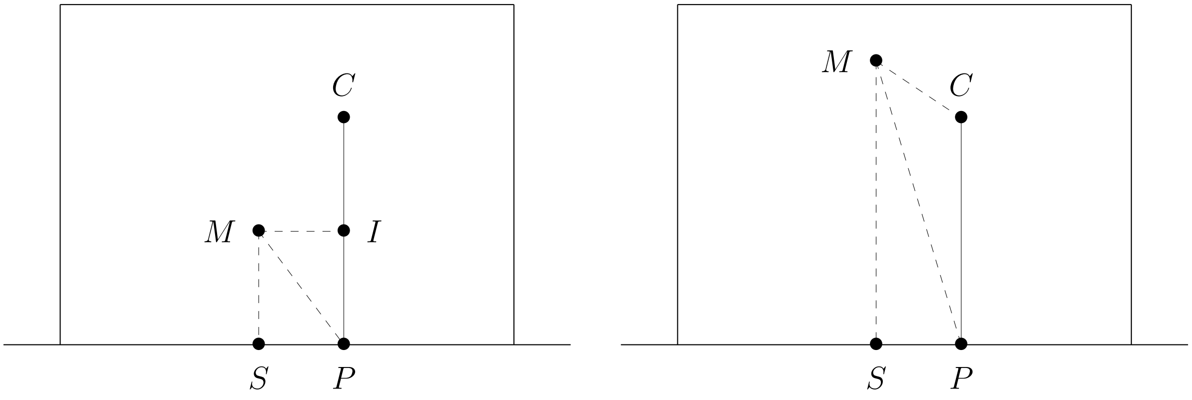
C Figures



Panel I: coastal d

Panel II: landlocked d

Figure 4: Mine-related transport infrastructure, coastal and landlocked destination



Panel I: $IP < CP$

Panel II: $IP > CP$

Figure 5: Construction of the mine impact index, coastal countries

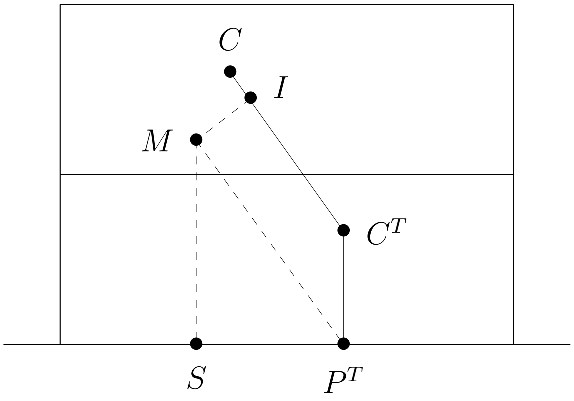


Figure 6: Construction of the mine impact index, landlocked countries

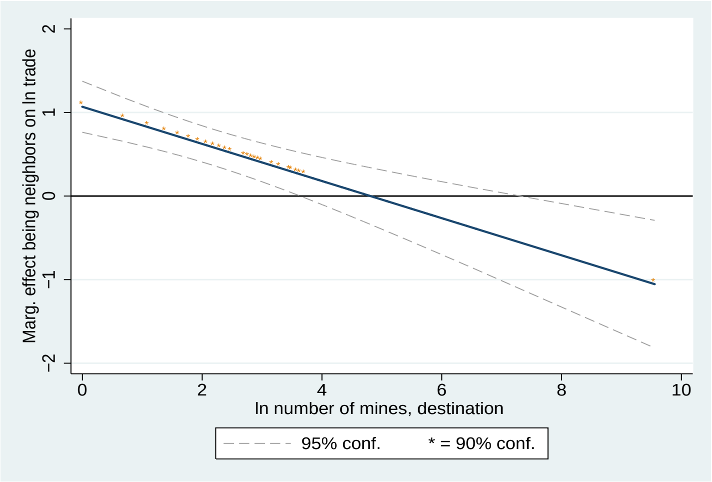


Figure 7: Marginal effect of N on imports, World sample (reg. 5a)

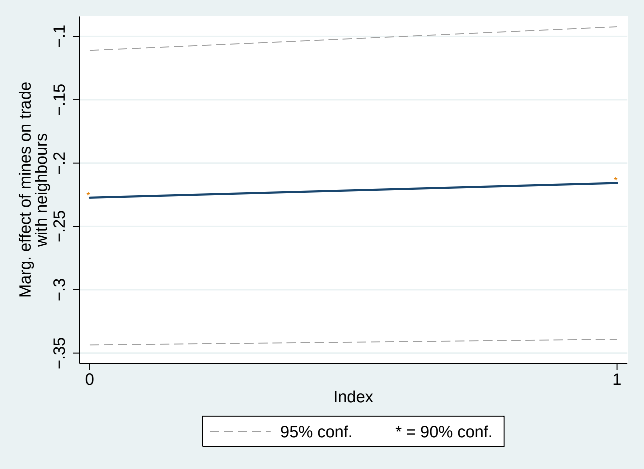


Figure 8: Marginal effect of M_d on imports from neighbors, World sample (reg. 6a)

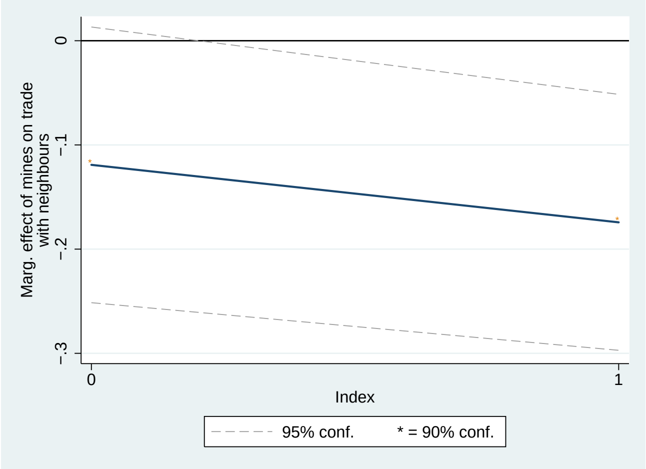


Figure 9: Marginal effect of M_d on imports from neighbors, non-OECD sample (reg. 6d)

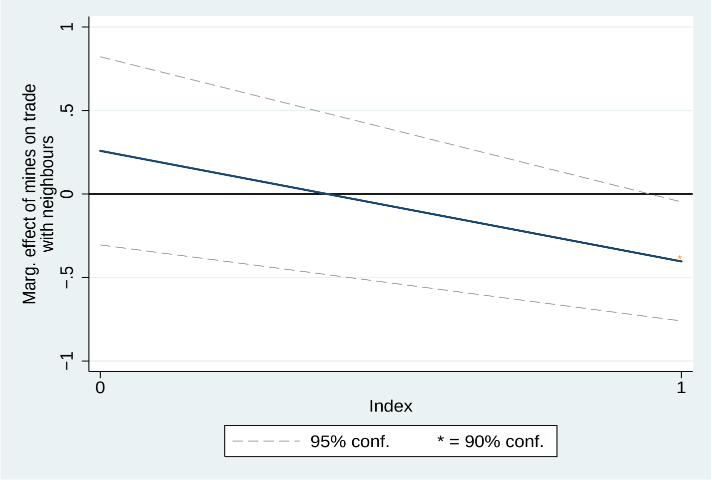


Figure 10: Marginal effect of M_d on imports from neighbors, African sample (reg. 6e)

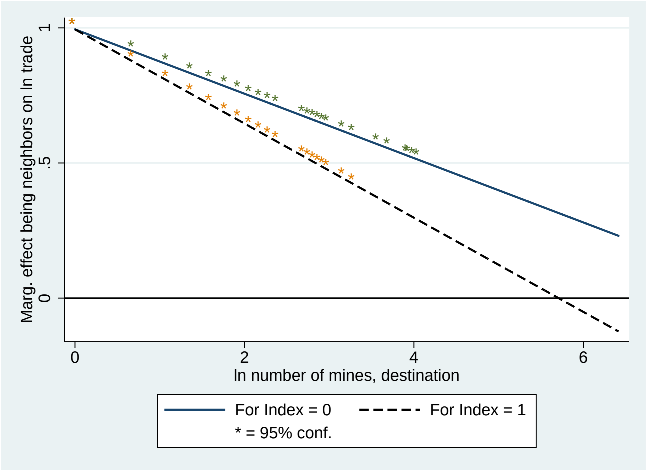


Figure 11: Marginal effect of N on imports, non-OECD sample (reg. 6d)

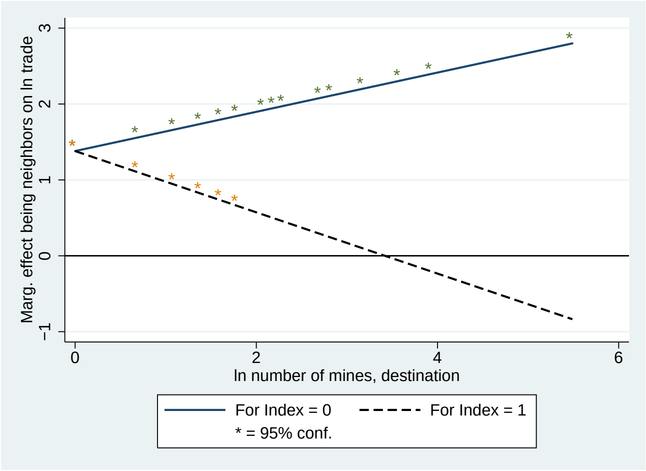


Figure 12: Marginal effect of N on imports, Africa sample (reg. 6e)

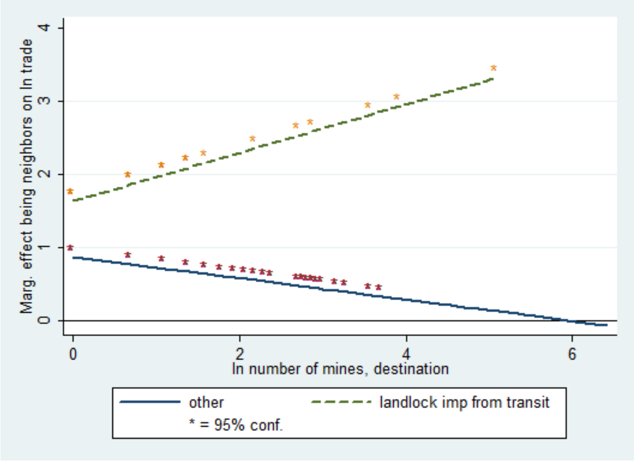


Figure 13: Marginal effect of N on imports, non-OECD sample (reg. 7d)

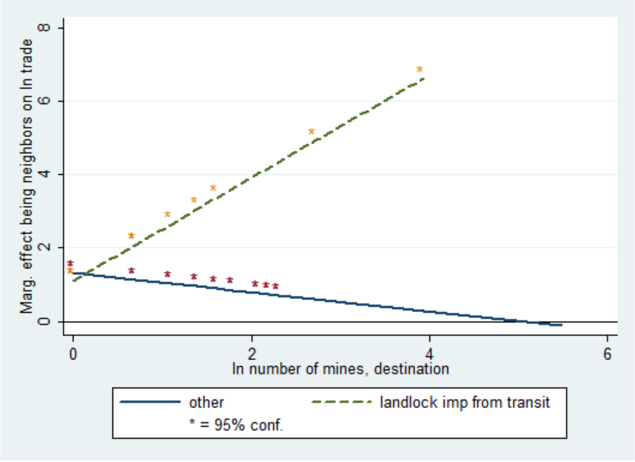


Figure 14: Marginal effect of N on imports, Africa sample (reg. 7e)

D Tables

Table 1: Imports as a share of total imports[1]

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

[1] ROW is the world minus OECD and Africa. Means are means across countries for 2006 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.

Table 2: 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%

Note: 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.

Table 3: Top mining countries and mine impact index π_d

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: $\pi_d \in [0,1]$ is an index capturing the extent to which the mine-to-coast infrastructure overlaps with the location of d's consumers, and thus reduces their cost of importing from overseas.

Table 4: 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	2.50	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; $\pi_d \in [0, 1]$ is an index capturing the extent to which the mine-to-coast infrastructure overlaps with the location of *d*'s consumers, and thus reduces their cost of importing from overseas; α_d is a dummy equal to 1 if π_d is larger than its average of 0.46.

Table 5: The trade redirection effect of mines

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)
$\partial \ln imp / \partial N = 0$					
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; $NM_d\alpha_d = NM_d$ * mine impact index in the destination country. Origin and destination fixed effects are included, and so are the controls listed in Table 5. 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)
$\partial \ln imp/\partial N = 0$					
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 effects are included, and so are the controls listed in Table 5. 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) World	(b) non-US	(c) OECD	(d) non-OECD	(e) 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

Note: N = neighbour; NM_d = Neighbour * mines in the destination country; $NM_d\alpha_d = NM_d$ * mine impact index in the destination country; NOG_d = Neighbour * oil and gas fields in the destination country; $NOG_d\alpha_d^{OG} = N)G_d$ * oil and gas field impact index in the destination country. Origin and destination fixed effects are included, and so are the controls listed in Table 5. 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.1

E Technical Appendix - Not for Publication

E.1 Measuring the mine impact index

To measure the mine impact index we need to find first the geographical midpoint of mines in each country (M), the urban population weighted geographical midpoint of main cities (C), the location of the country's main container port (P), and the point on the shoreline nearest to point M (S). For point M, given the latitude and longitude of each mine i in country j, we calculate their geographic midpoint on the globe as follows:

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

where:

$$\begin{aligned} x_j &= \sum_i \cos(latitude_i * \pi/180) * \cos(longitude_i * \pi/180)/I_j \\ y_j &= \sum_i \cos(latitude_i * \pi/180) * \sin(longitude_i * \pi/180)/I_j \\ z_j &= \sum_i \sin(latitude_i * \pi/180)/I_j, \end{aligned}$$

and where I_j is the total number of mines with available WGS 84 coordinates in country j.

We follow a similar procedure for point C. However, instead of summing over each mine i, we sum over each city, and weigh each city by its population in 1950.[40] The data on cities comes

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

from the UN's "World Urbanization Prospects" database of urban agglomerations with at least 750,000 inhabitants in 2010, to which we add hand collected city coordinates. We choose the earliest available figure for population, because current population sizes may have been influenced by infrastructure itself. With weights, z_j becomes: $\sum_i \sin(latitude_i * \pi/180) * p_i / \sum_i p_{ij}$ where p_{ij} is the population of city i in country j. The midpoint of cities will thereforee 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 for all countries with at least on port included in the ranking. For countries that are not included in the AAPA ranking, we use, when possible, 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.[41] Finally, for countries that are neither included in the AAPA ranking nor reached by Maersk Line, we identify the main commercial port by conducting a series of internet searches.[42] We coded as "port co-ordinates" those of the port's nearest city, which we got from the World Urbanization Prospects database, and, for smaller cities, from Wikipedia/GeoHack.

To find point S, the coastal point closest to the midpoint of the mines, we rely on the "Global Self-consistent, Hierarchical, High-resolution Shoreline Database" (GSHHSD) provided

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[41] Maersk Line has the largest market share (18%) according to http://www.shippingcontainertrader.com/facts.shtml.

[42] 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.

by the National Oceanic and Atmospheric Administration (NOAA).[43] The database provides the co-ordinates of all coastlines in the world, and 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 purposes, it is best to use level 1, which excludes the possibility that we find S on the shore of a lake, and a low resolution, which builds up the world's coastlines from $64,000$ coordinates.[44] For each country, we calculate the distance between point M and each coastal point, and pick S as the coastal point that minimizes such distance. Following this procedure, point S for the mines of South Africa is only 50km from the actual port of Durban, while point S for the mines of the Democratic Republic of Congo turns out to be on the coast of Angola.

Having identified points M, P and S for each country in our sample, we move to calculate the mine impact index as described in (6)-(8). To accurately measure distances between pairs of points, we use navigation formulas.[45] The distances MP, MS, and CP are great circle distances.[46] 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.[47] The distance IP is then found by calculating the "along track distance": $\arcsin(\sqrt{\{}(\sin(CM))^2 -$

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

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

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

[46] That is, 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.

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

$(\sin(xte_{CMP}))^2\}/\cos(xte_{CMP}))$.

E.2 Robustness

E.2.1 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, large countries may trade disproportionately more with neighboring countries. This section explores this possibility by adding an interaction between the log of surface area in km^2 (which we label by A_d) and the neighbor dummy to our main specification (the one reported in Table 6). 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. However this effect does not explain why we find a negative effect of mines on trade. In fact, since larger countries have more mines and tend to trade more with neighbors, the trade re-direction effect is *stronger* after we control for country size.

E.2.2 "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.[48] 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 trade.

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 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).

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[48] 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 therefore assume that missing trade represents no trade in COMTRADE as well.

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.[49] 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 therefore more likely to affect 2006 trade than 1986 trade. We start from our main specification (the one reported in Table 6), and estimate the following two-stage model for non-resource FDI with the Heckman (1979) correction:

$$\Pr(\mathrm{imp}_{od} > 0)|N_{od}M_d, N_{od}M_d\alpha_d, N_{od}, \ln\tau_{od}) = \Phi(\gamma_1 N_{od}M_d + \gamma_2 N_{od}M_d\alpha_d + \gamma_3 N_{od} + \gamma\ln\tau_{od}) \tag{14}$$

$$\begin{aligned} &\mathrm{E}[\ln\mathrm{imp}_{od}|\mathrm{imp}_{od} > 0, N_{od}M_d, N_{od}M_d\alpha_d, N_{od}, \ln\tau_{od}, a_o, a_d] = \\ &\qquad = k - \ln\tau_{od} + a_o + a_d + \beta_1 N_{od}M_d + \beta_2 N_{od}M_d\alpha_d + \beta_3 N_{od} + \rho_{od}\sigma_{od}\phi_{od} + v_{od} \end{aligned} \tag{15}$$

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

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[49] This can be rationalized using recent theories that split entry costs into fixed and variable costs, and predict that only the most productive firms can overcome the fixed costs.

stage (15) to correct for sample selection bias and is calculated from the estimated parameters of the first stage (14). 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 all cases, the first stage shows that mines make it less likely that countries trade with neighbors at all, consistently with our hypothesis; and that entry costs correlate negatively with trade. Moving to the volume of trade in the second stage, we still find that countries with more mines import relatively less from neighbors. Again, we find that in Africa this effect is only significant and negative if mines have a high potential for re-directing trade ($\alpha_d = 1$).

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 therefore 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 for doing this is that it is unlikely that any country truly has no mine at all, while it is probably due to random measurement error that some mines do not appear in the MRDS data. We perform a final check and regress trade on an interaction between neighbor and mines, where mines is the log number of mines as reported by the US Geological Survey (Table 13). Panel A includes only NM_d, while Panel B also includes $NM_d\alpha_d$. 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 a significant trade re-direction effect, which in Africa depends on the mine impact index as before.

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

Note: N = neighbour; NM_d = Neighbour * mines in the destination country; $NM_d\alpha_d = NM_d$ * mine impact index in the destination country.; NA_d Neighbor * log area in km2 of 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 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; $NM_d\alpha_d = NM_d$ * mine impact index 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; $NM_d\alpha_d = NM_d$ * mine impact index 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.