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Rail Revival in Africa? The Impact of Privatization

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Preliminary Work

Abstract

I explore the impact of railway privatization on local economic activity in Sub-Saharan Africa using a novel spatial panel dataset – light density measured by satellites at night. The data comprises a panel of 0.3x0.3 decimal degrees grid cells over the period 1992-2010, covering thirty-two countries. I find a positive, significant and localized (less than 20km) impact of privatization. Furthermore, the results suggest that the impact grew over time. Placebo tests prior to privatization suggest the effect is not due to selection bias – areas close to privatized lines were, if anything, in relative decline prior to privatization.

1 Introduction

Sub-Saharan Africa is known for its dilapidated infrastructure, notably in the railway sector. An ongoing macroeconomic challenge for the region is that of how to scale-up public investment effectively, allocating funds to those projects with high returns. Whether the returns to railway reform or new lines are high is, however, a non-trivial question. Several recent studies

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calculate returns by exploiting the quasi-experiment of colonial railways built primarily for military purposes: Donaldson (2010) shows evidence of large returns in India, whilst Jedwab and Moradi (2012) show similar results for Ghana. These papers offer a persuasive approach to identification, though partially at the expense of contemporary policy implications. Banerjee, Duflo and Qian (2012) provide evidence of a moderate causal impact of transport infrastructure on GDP per capita in China – but the context differs from Sub-Saharan Africa, and the results apply to transport infrastructure in general, rather than any particular medium. Whether today's policy-makers in Sub-Saharan Africa can interpret any of these results as justification for further railway expansion is debatable. The results of historical studies in particular may not apply when we consider that the competition for transport services from road networks in Africa has increased radically since the colonial era.

The relative lack of research on the returns to modern railways is partly explained by the lack of a convincing approach to identification[1]. But far more importantly for Sub-Saharan Africa, there have been a dearth of examples of new railway building in recent decades, making the question of 'random placement' somewhat irrelevant. Beyond this, much of the existing literature focuses on the economic effects of *building new* infrastructure, but in many contexts, Africa included, the most pressing question is how to *manage existing* infrastructure. How much can we justify spending on rehabilitation and repair of the existing stock of public capital? How much finance should be directed towards maintenance? Who should make these decisions, and who should operate the infrastructure?

In this paper, I focus on the latter question by looking at the impacts of concessioning (or privatization[2]) of railways in sub-Saharan Africa. Since 1990, concessions have been granted in 16 countries[3], with a few more countries having begun the process, and many others still with state-run rail. The hope was that concessioning could lead to improved rail services and relieve governments of costly subsidies to state-owned rail companies. By 2010, almost 70% of the entire sub-Saharan African rail network (excluding South Africa) was wholly or partially privatized. Associated with these concessions has also been international donor support to fund new investment in rail. These concessions seem to have improved the running of the railways (Bullock (2009)) – freight traffic has generally increased, asset and labor productivity improved, and the service become more reliable. That said, there appears to exist no rigorous attempt to evaluate the broader economic impacts. In principle, such a policy evaluation would be difficult given the lack of comparable pan-African spatial data on incomes, but in this paper I am able to make a credible first attempt at policy evaluation using a useful proxy

[1]Though a recent novel approach has been to use distance to straight lines connecting cities as an instrumental variable – see Banerjee, Duflo and Qian (2012) for an example.

[2]I will use these interchangeably throughout, though there are distinctions.

[3]In addition, some countries have one or more dedicated private-run railway lines.

for income available at high resolution for the period 1992-2010: data on light density at night.

This paper then aims to establish whether privatization had any appreciable impact on local economic activity. Since concessions were not granted randomly (a big concern is that the search for concessionaires is likely to be more successful if large profits are anticipated from running the line), identifying the causal impact of privatization is difficult. Having said that, there is some evidence (see Bullock (2009)) to suggest that concessioning has often occurred as a result of pressure from multilateral and bilateral organizations, and this pressure may be less related to the expected economic activity along the line. Furthermore, privatizations were often delayed/postponed:

> *"The reform momentum accelerated in the 2000s, but implementation has often been a slow process, typically taking three to five years, sometimes much longer."*
> *World Bank (2010)*

In the case of the Djibouti-Ethiopia line a planned concession in 2002 never materialized, despite favorable conditions and several serious bidders. Such delays make it less likely that the eventual timing coincided with positive railway-specific shocks. However, rather than working off this assumption, I exploit the panel structure by carrying out placebo-type checks to assess the key endogeneity concern.

The paper proceeds as follows: in Section 2 I set out the context by describing the key features of Africa's rail network and its privatization experience, Section 3 briefly reviews the related literature, Section 4 contains toy trade models to capture mechanisms, in Section 5 I describe the data and empirical strategy, Section 6 contains the results and Section 7 concludes.

2 Context[4]

2.1 The State of African Rail

The African rail network today is not much different from its state towards the end of the colonial era. The thirty or so countries that have lines share very similar experiences: many decades ago an intial track would be laid from some interior mine or trading hub toward the main port, and subsequently a number of branch lines would be built. These sparse networks were rarely connected across countries – except for the southern African network where lines extend from South Africa (where the network is far denser) up as far as the Democratic Republic of Congo. Several landlocked countries in sub-Saharan Africa have no rail network

[4] I draw heavily from the excellent work in World Bank (2010).

at all – Niger, Chad and the Central African Republic being examples. For sub-Saharan Africa as a whole, very few new tracks have been laid in the past few decades. To some the greatest need is to expand the network, and in particular to promote inter-regional connections in the hope of a truly trans-African railway system. Proposals of such a network have been put forward for decades – the Union of African Railways proposed 26,000km of new construction in 1976 for instance, from a current base of 69,000km. Such proposals have regularly fallen through, with economic feasibility a serious question – the lack of existing inter-regional trade in particular suggests these links may be used only lightly (World Bank (2010)).

It is important then to recognize what does, and does not, justify significant network expansion. The fact that Africa's network is sparse (with several countries having no lines at all) does not alone imply high marginal returns to new lines. More important is that there exist large sources of demand for rail transport in currently underserved locations. This factor is rarely met. The benefits are likely too low to justify the costs – the World Bank estimates the cost of a single-track non-electrified railway on flat terrain to be at least $1.5 million per km (rising to $5 million on rough terrain), costing the proposed 26,000km expansion at a minimum of $39 billion.

A more pertinent question is then exactly how costly it would be to reform and rehabilitate the existing network, rather than expanding it. The network is of course out-dated, with some lines built over 100 years ago. As of 2009, only around 80% of the network was operational, with the rest stalled by poorly maintained track and damage from civil wars. Even when lines are running, transit time can be horrifically long – e.g. the 3,000km trip from Kolwez, DRC to Durban takes 38 days, an effective speed of 4km/hr (World Bank (2010)). The network is almost all non-electrified with manual signaling systems (both partially consequences of poor electricity infrastructure) and narrower gauges than most of the rest of the world[5]. Beyond these physical limitations, over the past few decades the network has faced stiffer competition from steadily improving and increasingly liberalized road networks. As a result, the market share of rail transport has fallen.

At what cost can the network be revived? The World Bank estimates that there is a backlog of $3 billion of investment, or $300 million/year spread over 10 years. On top of this there are regular outlays needed for maintenance, track reconstruction, facilities and rolling stock expenditure. These amount to $200 million/year indefinitely. Clearly these figures compare favorably with the minimum $39 billion to expand the network by roughly 40%, but even so, can this investment be justified? The re-investment cannot realistically be done

[5]Most use the Cape gauge (3'6) or the meter gauge (3'3$\frac{3}{8}$) whilst standard gauge (4'8$\frac{1}{2}$) is the most widely used globally. Loads can be heavier given a wider gauge. Note also that multiple gauges (as in Africa) can lead to interoperability problems, but the disconnectedness of the African network means this doesn't matter so much.

internally – most railways require government support to maintain basic operations, with passenger services usually operating at a loss[6]. A third party financier would be needed. A serious question is then whether the rails should be revived by external intervention, or whether this finance is better injected elsewhere. An economic question here is whether there exists strong externality arguments for donor support of rail systems. One argument might be some kind of "big push" argument in which, though demand is insufficient to generate large revenues today, a coordinated increase in public investment might shift the economy into a better equilibrium. In fact, investing in rail is one example that Murphy, Shleifer and Vishny (1989) draw on in their work formalizing the "big push". Another argument is that there are environmental benefits of rail transport instead of road (di Borgo, in Proparco (2011) claims an 85% reduction in carbon footprint per ton transported). This could arguably be dealt with using road charges, but it seems these are rarely implemented in reality.

2.2 Private Sector Involvement since the 1990s

Of course, major donor support for rail rehabilitation is not the only option for Africa. Reforming management is another route towards service improvements and lower transport costs. African rail was predominantly a state-dominated activity until the mid-1990s when many states began to privatize their networks. Usually a concession would be granted (16 have been granted since 1990) – usually a foreign private company would sign an agreement to operate and maintain the railway line for a certain period (usually 15 to 30 years), with some or all of the assets still under state ownership. Concessionaires have freedom to set freight and passenger rates, though must also pay fees and taxes to the state.

African governments were initially reluctant to grant concessions – they came under bilateral and multilateral donor pressure to do so, and often their own financial pressure (since existing state-run railways required large subsidies). In reality, in most cases the government went on to gain financially from concessioning – the financial flows reversed, with fees and taxes paid by the concessionaire exceeding the subsidies that previously went in the opposite direction. This is a significant advantage of concessioning. It should be noted though that with concessions came financial support from IFIs, particularly IDA, an arm of the World Bank. This funding would be for technical assistance, labor retrenchment[7] and infrastructure rehabilitation. IDA funding amounts to $773 million since 1996 – a non-trivial amount, making it clear that the concessioning experience was a hybrid of management change and donor support, not a pure alternative. A sense of IFI involvement is given in Table 1.

[6]This is of course common even outside of Africa, e.g. Amtrak in the US.

[7]E.g. $45 million for retirement rights of 4,500 employees of DRC's SNCC railways.

Company	Countries	Year of Concession	Total Support ($US mill)	
			IDA	IFC
Sitarail	Côte d'Ivoire, Burkina Faso	1996	21	none
Beitbridge Bulawayo Railway	Zimbabwe	1999	none	none
Camrail	Cameroon	1999	113	none
Central East African Railways Company	Malawi	2000	10	none
Railway Systems of Zambia	Zambia	2002	35	none
Madarail	Madagascar	2003	65	none
Transrail	Senegal, Mali	2003	45	none
Companhia dos Caminhos de Ferro da Beira	Mozambique	2005	110	none
Transgabonais	Gabon	2005	none	none
Nacala Railway	Mozambique	2005	20	none
Kenya Railway Corporation – Uganda Railways Corporation	Kenya-Uganda	2006	74	32
Tanzania Railways Corporation	Tanzania	2007	35	44
Société nationale des chemins de fer du Congo	DRC	2011	243	none

Source: Proparco (2011)

Table 1: IDA and IFC Support

The overall experience of privatization has been positive – labor productivity and asset productivity typically doubled, freight traffic increased internal business practices and service reliability tended to improve. These improvements came as concessionaires actively sought new traffic and laid off workers[8]. The broader economic impacts are much more difficult to gauge, and the subject of this paper. It may be that railway service and government finances improved, but was there any noticeable impact on the local economy? I try to answer this question in later sections.

The evidence on privatization is not all positive, however. Private operators have tended to disappoint the high initial expectations of governments, particularly in light of their relative unwillingness to finance re-investment and improve the quality of passenger services. Private owners are as yet not fully self-sufficient with external support still needed to finance the investment backlog. Privatization is no panacea, but it seems nevertheless to have been a better policy than the alternatives.

2.2.1 Sitarail and Camrail: A Success Story

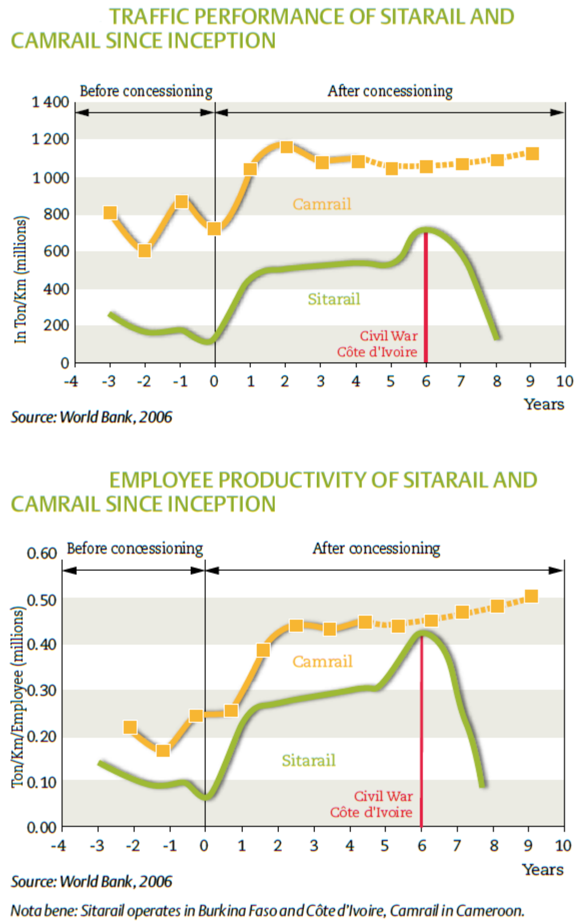
In 1995 the first concession was granted to Sitarail – a 15-year responsibility to operate the railways of Burkina Faso and Côte d'Ivoire[9]. The next concession followed in 1999 in Cameroon – Camrail was granted a 20 year concession to operate the Cameroon National Railway[10]. Both companies are managed by Bolloré Africa Logistics – the largest private concession operator in Africa, and one of the largest private employers, with over 20,000 staff. Sitarail and Camrail seem to provide two examples of successful privatization. In both cases traffic and productivity increased following the concessioning, as can be seen in Figure 1.

Sitarail suffered noticeably from the civil war in Côte d'Ivoire in 2002 (service was completely suspended for 9 months), but otherwise both concessions led to improved rail service. The task of this paper is to assess whether these improvements of service are representative of African privatization in general, and whether they translate into local development.

2.2.2 The Djibouti-Ethiopia Failure: A Cautionary Tale

Not all attempts to privatize lead to success. The Djibouti-Ethiopia experience is a case in point, highlighting the issues that come up in concession attempts and more importantly, the long delays between proposals and implementation – these delays form part of my empirical argument that privatization is not likely to be correlated with railway-specific shocks to economic activity.

[8]Often inciting hostile media coverage, e.g. with Camrail in Cameroon.
[9]See http://www.vecturis.com/operations/closed/sitarail.html.
[10]See http://www.vecturis.com/operations/closed/camrail.html.



Source: Figure 1+2 of Richard Bullock piece, Proparco (2011)

Figure 1: Sitarail and Camrail Successes

Arthur Foch reviews this particular concession experience in Proparco (2011). As is common across Africa, a public company (CDE) ran the Djibouti-Ethiopia railways, and ran them badly. The government was under such financial pressure by 2002 that it approached the Agence française de développement (AFD) and the European Commission. The AFD and EC promised to grant aid on the condition that a concession be granted; the states agreed. What followed was a protracted, and ultimately unsuccessful, attempt to concede the line, despite favorable circumstances[11]. Discussions with the COMAZAR consortium began but broke down by 2007, then discussions began with Kuwaiti firm Al Ghanim & Sons, again breaking down. To this day a concession has not been granted.

The Djibouti-Ethiopia experience highlights the potential difficulty in conceding effec-

[11] For example the Ethiopia-Eritrea conflict led to the redirection of freight traffic through Djibouti.

tively. In this case there was blame on both sides – the COMAZAR and Al Ghanim traffic projections were overly optimistic and the Djiboutian and Ethiopian states themselves failed to understand the requisites of the would-be concessionaires for signing.

Beyond all this, experiences like that of Djibouti-Ethiopia form the counterfactual in the econometrics to come – the rough idea is that we can form a plausible counterfactual of economic activity by using data from areas close to railways that were not yet, or never, privatized (despite plans to do so).

3 Literature Review

This paper is closely related to three strands of literature: the first strand comprises the use of light density as a proxy for economic activity, the second is that of empirical work on the effects of transportation infrastructure and the third is on the impact of privatization.

Economic literature using light density data is in its infancy. Henderson et al. (2012) has been one of the eye-opening papers[12] arguing for the validity of the data as a measure of economic activity. They did the ground work of carefully processing the lights data at country-level to supplement existing measures of GDP. They present a number of advantages of the light data relative to existing income data: one of these is that the calculation of GDP is extremely difficult, and particularly so within developing countries where much of economic activity is outside of the formal sector. The lack of capacity of statistical offices in the developing world only exacerbates this. An even more important drawback of existing data is the lack of comparable subnational income data. Whilst the light data has its own problems, a great asset is that it can be aggregated to any spatial unit desired, and its measurement is consistent across space – not varying with the whims and capabilities of national statistics offices. To be precise, Henderson et al. (2012) go beyond presenting arguments, and develop a framework for combining lights measures with income measures in order to improve estimates of economic growth.

More important for this paper, they also provide evidence of the validity of using the light measure as a proxy for economic activity at a very local scale. One example they look at is the discovery of gems (thought to be the world's largest sapphire deposit) in late 1998 in southern Madagascar. The area has boomed, and this is clearly reflected in the satellite data - in 1998 there were no light pixels visible in the area, but over the following years there was high growth in both the amount of light and its luminosity. It is this kind of pattern in the data we will look for when considering the effects of privatization - namely whether the lights

[12] Though several papers had already shown the relation of the lights data to economic activity – see Henderson et al. (2012) for references (and also for a more detailed description of the light data than will be found in this paper).

in those areas that become connected to privatized railroads get larger and brighter, relative to areas connected to state-run rail.

Chen and Nordhaus (2010) also write about the value of lights as a proxy. Their conclusion is somewhat more pessimistic than that of Henderson et al. – they argue that the lights data has little use for countries with decent statistical capacity, but may have value where that is not the case. This is of course the case for Sub-Saharan Africa where there is basically no alternative source of geo-referenced panel income data.

Convinced of the value of light data as a proxy for local economic activity, a number of economists have used the data in empirical work. A great example of such a paper is that of Michalopoulos and Papaioannou (2013a) on the long-run impact of pre-colonial ethnic institutions on development in Africa. To explore the impact of ethnic institutions which both cross and are contained within national borders, the authors have need of subnational data on economic output. For this, the lights work well. Relevant to this study, they also provide additional support that it makes sense to use the lights data for Africa: using micro-level data from the Demographic and Health Surveys (DHS) they find a strong correlation (of about 0.75) between lights and a composite wealth index.

Several other studies use the data convincingly in empirical work: Storeygard (2012) on the effects of transport costs on African cities; Pinkovskiy (2013) looks for discontinuities in lights at country borders to argue for the effects of national institutions; Baum-Snow et al. (2012) look at the effect of transportation infrastructure on decentralization of cities in China; Bleakley and Lin (2012) on path dependence of the location of economic activity in the US.

Most empirical studies using light data have focused on cross-section variation. In this paper the identification hinges on using both cross-section and time variation.

The second branch of related literature is that on the effects of transportation infrastructure. On railroads, Donaldson (2010) used colonial era in India as a quasi-experiment – the British primarily built the vast network of railways with military motives in mind, rather than economic, alleviating concerns of endogenous placement. Donaldson finds that being connected by a railroad rose real agricultural income in a district by around 16 percent. A similar approach to identification is taken in Jedwab and Moradi (2012) – they find large effects of rail connectivity on cocoa production, and the effects were persistent: railroad areas are more developed today despite the unimportance of railroad transportation. Both papers test the empirical predictions of trade models convincingly, but to aid the contemporary policy debate, research on contemporary investments is needed - this paper represents one step in that direction.

A problem in general in evaluating transportation infrastructure is that of endogenous placement. Casaburi et al. (2012) overcome this using a regression discontinuity design in the context of a rural road rehabilitation program in Sierra Leone – improving roads causes a fall in crop prices. Gonzalez-Navarro and Quintana-Domeque (2012) provide a rare example of experimental evidence in this area - they manage to randomize street paving in Mexico, finding effects on wealth and consumption. Banerjee et al. (2012) use straight line instruments, whilst Faber (2012) constructs least cost paths to use as instruments for route placements – both of these studies on the National Trunk Highway System in China. Whilst plausible cross-sectional instruments have been used (also see Michaels (2008), Duranton and Turner (2011)), there has been little success in finding a valid instrument in the literature with time-variation. In this paper, where the identification comes from the panel variation, and the endogeneity concern is not from endogenous *placement* but rather from endogenous *choice* of railways to privatize, my empirical approach is diff-in-diff, rather than IV.

Finally, this paper relates to existing work on the effects of privatization. In principle, we might expect privatized firms to have stronger incentives to improve productivity and make smart investments. On the other hand, impacts are likely to depend on the strength of the case for government intervention in the first place. For instance, a private monopoly may be more likely to charge higher prices (which would mean higher transport costs in the context of railways) and supply less than the social optimum than a state-run monopoly.

The empirical evidence is however largely supportive of the positive claims. Megginson and Netter (2001), in a broad review, conclude that privately owned firms are more efficient and profitable than comparable state-owned firms, and that privatization is largely more effective than alternative non-privatizing reform measures. Estrin et al. (2009) evaluate the evidence for post-communist countries, taking a more balanced view. They find that privatization to foreign owners tends to improve firm performance considerably, whilst privatization to domestic owners has had smaller, and varied, impacts. Contrary to some models, privatization is not found to reduce unemployment – private owners tend actually to keep employment higher than their predecessors.

To my knowledge, there is little notable empirical work on the effects of rail privatization. On privatization of infrastructure, Kosec (2012) employs a micro-level pan-African panel dataset (as in this paper) to explore the impact of private sector participation (PSP) in the water sector since 1986. She finds that PSP decreases diarrhea prevalence amongst urban-dwelling under-five children by 35%. Kosec addresses identification more convincingly than much of this literature by instrumenting for PSP using the share of non-African, private water market controlled by the relevant former colonizer – a variable which is strongly positively correlated with PSP in the country. In a related study, Galiani et al. (2005) look at the Argentinian privatization of water provision in the 1990s. The impact again is beneficial: child mortality falls 8 percent in the areas that privatized, with larger effects in the poorest areas.

By and large, existing evidence suggests that privatized firms are more efficient, and that this extends to tangible benefits to consumers. This paper contributes by presenting new evidence on the effects of the privatization of rail. In what follows, I take a stance on the hypothesis that successful privatization of rail should lower transport costs through improved management and greater investment. I work through the implications of a fall in transport costs using a basic trade model.

4 Model

It is common to model new transportation infrastructure as a fall in iceberg transport costs leading to greater trade, consumption and welfare[13]. Improved management and new investment in rail can be modelled in the same way – though in this case it may be that the transport cost fall is less stark (i.e. it is not a fall from $\tau = \infty$ which could be the case if no infrastructure exists beforehand). The model then takes this stance, with the key comparative static being the fall in τ. That said, it is worth understanding what τ comprises in this context. The most obvious transport cost is the freight tariff – these range from \$0.03 to \$0.05 per net tonne-km, a figure comparable with similar countries. These rates tend to be much smaller than road rates, but rail costs add up when cost of transport to and from the railhead is considered (particularly given the sparse network in Africa – distances to and from the rail can be large). These financial costs are not all that matters though: total transit time is important, as is frequency of service, reliability and safety. These may well be what improved most as a result of privatization, and each can have a τ interpretation. Consider reliability for example: if the train only reaches its destination 50% of the time, then on average $\tau = \infty$ every other trip. Effective transport costs are then much higher than the headline freight tariff. With these ideas in mind, I proceed to the model.

4.1 Three-Region

Three regions indexed by $r \in \{1, 2, 3\}$ lie along a line (connected by a railway). Region 2 is our 'connected' region (or 'interior'), whilst the others are relatively isolated. Each region produces only one good, with locations $1, 2, 3$ producing goods A, M, S respectively. Technology is symmetric and linear in the only factor input, labour. We have then that $Y_r = BL_r$ for $r = 1, 2, 3$.

[13]E.g. Donaldson (2010) modifies the Eaton and Kortum (2002) model in which transport cost falls lead to welfare gains through increased specialization according to comparative advantage.

Preferences are identical across regions and represented by symmetric Cobb-Douglas utility so that $u_r = c_{Ar}^{\frac{1}{3}} c_{Mr}^{\frac{1}{3}} c_{Sr}^{\frac{1}{3}}$ for $r = 1, 2, 3$. This ensures that each good is shipped to all other regions, and income in each region is allocated equally between the three goods. Symmetry helps for simplicity throughout, but is not strictly necessary for the comparative statics.

We assume that the regions are equidistant along the line and employ the usual iceberg transport costs assumption – τ units have to be shipped for one unit to arrive in a neighbouring region, with $\tau > 1$. For shipping from one end of the line to another, τ^2 units have to be shipped. The transport cost is directly associated with the quality and management of the railway. In principle greater investment in the railway and/or improved management should lead to a fall in τ and an improvement in welfare for all locations along the line.

There is perfect competition in production so that prices are in line with marginal cost. With the normalisation that $p_{A1} = 1$ (price of A in region 1) together with the assumption on transport costs, the full set of prices is as follows:

$$p_{A1} = 1,\ p_{A2} = \tau,\ p_{A3} = \tau^2$$

$$p_{M1} = \tau p_M,\ p_{M2} = p_M,\ p_{M3} = \tau p_M$$

$$p_{S1} = \tau^2,\ p_{S2} = \tau,\ p_{S3} = 1$$

where $p_{S3} = 1$ by symmetry and p_M is to be determined. Finally, labour (supplied inelastically) is perfectly mobile across regions with total stock $\bar{L}$. Labour moves to equate per-person utility.

With the assumptions laid out, we can solve for optimal consumption, equilibrium labour supply and prices. Utility maximisation gives the following pattern of consumption:

		Region		
		1	2	3
Good	A	$\frac{1}{3}BL_1$	$\frac{\frac{1}{3}p_M BL_2}{\tau}$	$\frac{\frac{1}{3}BL_3}{\tau^2}$
	M	$\frac{\frac{1}{3}BL_1}{p_M\tau}$	$\frac{1}{3}BL_2$	$\frac{\frac{1}{3}BL_3}{p_M\tau}$
	S	$\frac{\frac{1}{3}BL_1}{\tau^2}$	$\frac{\frac{1}{3}p_M BL_2}{\tau}$	$\frac{1}{3}BL_3$

Transport costs have a direct effect of reducing consumption of imported goods. It will be shown that transport costs also affect the consumption of local goods through indirect (general equilibrium) effects.

Equilibrium in this economy consists of goods market clearing:

$$Y_A = c_{A1} + \tau c_{A2} + \tau^2 c_{A3} \rightarrow 2L_1 = p_M L_2 + L_3$$

$$Y_M = \tau c_{M1} + c_{M2} + \tau c_{M3} \rightarrow p_M 2L_2 = L_1 + L_3$$

$$Y_S = \tau^2 c_{S1} + \tau c_{S2} + c_{S3} \rightarrow 2L_3 = L_1 + p_M L_2$$

And labour market clearing:

$$L_1 + L_2 + L_3 = \bar{L}$$

$$v_1 = v_2 = v_3 \rightarrow \frac{\frac{1}{3}B}{p_M^{\frac{1}{3}}\tau} = \frac{\frac{1}{3}Bp_M^{\frac{2}{3}}}{\tau^{\frac{2}{3}}} = \frac{\frac{1}{3}B}{\tau p_M^{\frac{1}{3}}}$$

where v_r is indirect utility per worker in region r. From the last equation $p_M = \tau^{-\frac{1}{3}} < 1$. Since region 2 is better connected, the equilibrium price must be lower in that region to ensure constant utility across space (a lower price delivers lower purchasing power of A and S). The price difference between the interior and the endpoints is increasing in transport costs.

Using goods market clearing it follows that in equilibrium $L_1 = L_3$ (which is clear from symmetry anyway) and together with labour market clearing we have $L_1 = L_3 = \frac{\tau^{-\frac{1}{3}}\bar{L}}{1+2\tau^{-\frac{1}{3}}}$ and $L_2 = \frac{\bar{L}}{1+2\tau^{-\frac{1}{3}}}$. There is greater labour use in the interior (workers migrate there to benefit from the stronger trade connections).

We can now return to the consumption expressions and solve only as a function of exogenous parameters:

		Region		
		1	2	3
Good	A	$\frac{\frac{1}{3}B\bar{L}}{2+\tau^{\frac{1}{3}}}$	$\frac{\frac{1}{3}B\bar{L}}{2\tau+\tau^{\frac{4}{3}}}$	$\frac{\frac{1}{3}B\bar{L}}{2\tau^2+\tau^{\frac{7}{3}}}$
	M	$\frac{\frac{1}{3}B\bar{L}}{\tau+2\tau^{\frac{2}{3}}}$	$\frac{\frac{1}{3}B\bar{L}}{1+2\tau^{-\frac{1}{3}}}$	$\frac{\frac{1}{3}B\bar{L}}{\tau+2\tau^{\frac{2}{3}}}$
	S	$\frac{\frac{1}{3}B\bar{L}}{2\tau^2+\tau^{\frac{7}{3}}}$	$\frac{\frac{1}{3}B\bar{L}}{2\tau+\tau^{\frac{4}{3}}}$	$\frac{\frac{1}{3}B\bar{L}}{2+\tau^{\frac{1}{3}}}$

These are aggregate, not per capita, consumption expressions for a reason – for the most part the empirics will look at light density without adjusting for population[14], and whilst lights are considered to act as a good proxy for income, they better reflect consumption.

There are three effects of a fall in transport costs: a direct effect through more output reaching its destination, an indirect effect through prices (p_B increases) benefitting the interior and an indirect effect through labour migration away from the interior. The composite effect is reflected in the expressions above. After solving for the endogenous quantities we can see that a fall in τ leads to an increase in consumption of all goods in all regions with one exception – the aggregate consumption of own good M in region 2 actually falls. The reason is that only the indirect effect through labour migration is at work – labour has moved to regions 1 and 3 resulting in lower income in terms of good M and a subsequent fall in consumption of M. Of course, we don't see this kind of disaggregation in the data – at best the lights give a proxy for aggregate consumption in each region. It is the impact on aggregate consumption that is to be tested[15].

Indirect utility is equalised across regions, with $v_r = \frac{\frac{1}{3}B}{\tau^{\frac{8}{9}}}\ \forall r$. A fall in transport costs raises welfare for all workers.

[14]It is possible to give regression estimates a per capita interpretation by controlling for population using Gridded Population of the World data, but that data is partly projections and has to be interpolated – controlling for population is not too convincing here.

[15]Heterogeneity between effects on endpoints and midpoints of railway lines could also be explored in future, and compared with the predictions of the model.

4.2 N-Region

Suppose now that there are N regions indexed by $r \in \{1, 2, ...N\}$ each producing its own good, indexed by $i \in \{1, 2, ...N\}$. Utility in region r is now

$$u_r = \prod_{i=1}^{N} c_{ir}^{\alpha_i}$$

where $\Sigma\alpha_i = 1$. The N regions are again equidistant along a line. The transport cost between two regions j, k is $\tau^{|j-k|}$. I drop here the assumption of labour mobility and assume instead that labour is equally distributed across regions such that $L_r = \frac{\bar{L}}{N} = \tilde{L}\,\forall i$. This lack of mobility may actually be a more reasonable assumption when considering the short-run impact of privatization in Africa.

Consider first the case of region 1, at one end of the line. The local price of 1's good is again the numeraire; $p_{11} = p_{NN} = 1$. Demand for good i will be

$$p_{i1}c_{i1} = \alpha_i p_{11} B\tilde{L}$$

$$\Rightarrow c_{i1} = \frac{\alpha_i B\tilde{L}}{\tau^{i-1} p_{ii}}$$

And it turns out that foregoing labour mobility gives local price equivalence – i.e. $p_{ii} = 1\,\forall j$. This general model then only exhibits direct effects of transport costs with no mechanism through labour migration or prices.

Adding the simplification that $\alpha_i = \alpha = \frac{1}{N}\ \forall j$ and denoting $B\tilde{L} = Y$ we have

$$c_{i1} = \frac{\alpha Y}{\tau^{i-1}}$$

and it follows that

$$v_1 = \frac{\alpha Y}{(\tau \cdot \tau^2 \cdot \tau^3 \ldots \tau^{N-1})^{\alpha}} = \frac{\alpha Y}{\tau^{\frac{\alpha N(N-1)}{2}}}$$

This gives a simple closed form expression for indirect utility of region 1 in the presence of transport costs[16]. A fall in rail quality (fall in τ) reduces welfare in region 1 by reducing its consumption from all other regions (with no indirect effects, local consumption is unchanged).

[16] We get here that welfare is falling in the number of regions, which is counter-intuitive in some sense, but also misleading since this comparative static involves increasing regions (and goods), requiring consumers to consume some of every new good, and also keeping the transport cost between regions fixed when, if the length of the line is fixed, it would make sense to have a new transport cost parameter τ' with $\tau'^2 = \tau$.

Now that labour is immobile, there will be differences in utility across regions – regions at the end of the line are hit the worst by transport costs. In the general case, indirect utility is

$$v_r = \frac{\alpha Y}{\left(\Pi_{k=1}^{r-1}\tau^{r-k}\Pi_{j=r+1}^{N}\tau^{j-r}\right)^{\alpha}} = \frac{\alpha Y}{\tau^{\alpha\left(\Sigma_{k=1}^{r-1}(r-k)+\Sigma_{j=r+1}^{N}(j-r)\right)}}$$

v_r is largest where $\Sigma_{k=1}^{r-1}(r-k) + \Sigma_{j=r+1}^{N}(j-r)$ is smallest, which is at the mid-point of the line[17].

Whilst the preceding theory delivers the simple prediction of higher consumption following the fall in transport costs, the emphasis on symmetry across regions (and associated prediction of greatest income/welfare at the midpoint) may be misplaced, given that in Sub-Saharan Africa it is common for a line to consist of a large coastal city at one end, a natural resource hub at the other and small towns in between. Building these features into the modelling will be left for future work.

4.3 Level vs. Growth Effect

One policy question (and relevant for privatization in Africa) is whether a reduction in transport costs has a one-off level effect on consumption or longer-run effects by shifting the 'treated' region onto a higher growth path. In the model so far any effect has been static. Here I develop a basic extension to rationalize possible growth effects.

Assume now there are two periods, two regions. I will entertain the notion that a fall in transport costs makes trade in ideas cheaper, as well as trade in goods. Suppose utility is now

$$u_r = c_{Ar1}^{\frac{1}{2}} c_{Mr1}^{\frac{1}{2}} + \beta c_{Ar2}^{\frac{1}{2}} c_{Mr2}^{\frac{1}{2}}$$

where c_{irt} is consumption of good i in region r at time t. Production is as before, and labour immobile[18]. Welfare is such that we have $v_1 = v_2 = (1+\beta)\frac{1}{2}Y\tau^{-\frac{1}{2}}$.

Now suppose that in period 1 each region has the option to pay some cost $f(\tau)$ with $f'(\tau) > 0$ (in terms of own units of output) to have access to some superior technology in period 2, with $\tilde{Y} = AL$ where $A > B$. We can think of this as the entrepreneur learning better ways of producing from others, with the cost of that learning falling when transport costs fall. Ideas flow more easily when regions are more connected.

Entrepreneurs will invest in period 1 if welfare will be higher with the investment. When the investment is made, the maximization problem in region 1 is

[17] If N is odd, otherwise welfare is greatest at the two central regions.

[18] Though mobility would change nothing here since the two regions are fully symmetric, meaning mobility leads to the same labour supply at each.

$$\max c_{A11}^{\frac{1}{2}} c_{M11}^{\frac{1}{2}} + \beta c_{A12}^{\frac{1}{2}} c_{M12}^{\frac{1}{2}}$$

$$\text{s.t.} c_{A11} + \tau c_{M11} = Y - f$$

$$c_{A12} + \tau c_{M12} = \tilde{Y}$$

Yielding indirect utility (assuming region 2 also invests, which makes sense if we think of symmetry) of $\tilde{v}_1 = \frac{1}{2}\left(B\tilde{L} - f\right)\tau^{-\frac{1}{2}} + \beta\frac{1}{2}A\tilde{L}\tau^{-\frac{1}{2}} = \frac{1}{2}\tau^{-\frac{1}{2}}\left(B\tilde{L} - f + \beta A\tilde{L}\right)$. Regions make the investment if

$$\tilde{v}_1 > v_1 \Rightarrow \frac{1}{2}\tau^{-\frac{1}{2}}\left(B\tilde{L} - f + \beta A\tilde{L}\right) > (1+\beta)\frac{1}{2}B\tilde{L}\tau^{-\frac{1}{2}}$$

$$\Rightarrow \beta\tilde{L}(A - B) > f(\tau)$$

i.e. if the discounted gain in terms of output is greater than the cost. A reduction in transport costs from τ_1 to τ_2 will yield a ‘growth’ effect only if

$$\tau_2 < f^{-1}\left(\beta\tilde{L}(A - B)\right) < \tau_1$$

And the growth is essentially $\frac{A}{B}$[19].

Evidence of such a growth effect would be diff-in-diff results that show an increasing impact over time. Having said that, it would be difficult with that evidence to rule out the alternative hypothesis that new private railway operators improved the lines gradually (causing τ to fall over time, rather than once and for all). The empirics that follow can then only go so far in validating the models highlighted here.

5 Data

Shown in Figure 2, within ArcGIS I super-impose a grid of cells, each of dimension 0.3x0.3 decimal degrees (except where they overlap out of sample), to cover the subsample of African countries for which I have railway data. This sample comprises thirty-three countries, one of

[19] In this scenario it is also possible that the transport cost reduction initially causes consumption to fall. This is true unambiguously for the local good, but depends on parameter values for the import.

which is South Africa, which I omit from the regressions that follow[20]. The unit of observation is then the grid-cell-year, and using tools within ArcGIS I merge on each variable to the level of the grid-cell-year. This fine spatial approach makes it easy to distinguish between areas close to rail transport and areas far from rail.

The key dependent variable of interest is light density at night, available from the Defense Meteorological Satellite Program's Operational Linescan System (DMSP-OLS). Following the approach of others (for example Michalopoulos and Papaioannou (2013a)), light density is used as a proxy of local economic activity (and perhaps the only useful proxy of local economic activity for Africa with such broad coverage across space and time).

The light density variable I use is gas-flare adjusted in most regressions using shapefiles available from the NOAA. This adjusting simply entails setting to missing any light measures thought to be generated by gas flares as opposed to economic activity. There is significant bottom coding in the light variable, and following Michalopoulos and Papaioannou (2013a) in the regressions I use $\ln(0.01 + \text{lights})$[21].

The GIS data on railway location comes from Bullock (2009) and the Africa Infrastructure Country Diagnostic, associated with the World Bank. The data on railways was collected around 2007, and though it includes detailed information on the characteristics of each line, it is only a cross-section. To transform the ownership data (state/privatized) into a panel, I use various sources to pin down the year of privatization (and the year of the line's return to being state-run, if appropriate). These include wikipedia, http://sinfin.net/railways/world/index.html, Proparco Issue 9 (2011) and Bullock (2009). Where the month of privatization is known, I opt to code the year of privatization as the following year if the month of privatization is in the last three months of a calendar year[22] (i.e. a privatization of December 2005 would be coded as having a year of privatization of 2006). Table 1 in the Appendix summarizes the ownership data. As for the panel dimension of railway lines, to the best of my knowledge, only one line in the dataset was built between 1992 and 2010[23] – the Beitbridge Bulawayo Railway (BBR) in Zimbabwe, completed in 1999. I make sure my dataset accounts for this, though in terms of the whole railway system, we can essentially think of it as having no panel dimension. With the railway data in hand, I use tools in ArcGIS to calculate the coordinates of the nearest railway line to each grid-cell, and the details of its ownership. I use the globdist

[20] My justification for this is simply that South Africa is an outlier with a significantly denser rail network and much greater GDP.

[21] This approach is also taken for population. In future work I will explore the robustness of the results to using Poisson and Negative Binomial regressions with the lights dependent variable left unadjusted (i.e. not logged).

[22] This is somewhat arbitrary, but it seems sensible, for example, to not treat a year as having a privatized railway if that railway was only privatized at the end of the year.

[23] I will gladly be corrected on this, and will update the dataset accordingly.

module in Stata to calculate distances from each grid-cell to the nearest line.

Further controls I add include: population (from Gridded Population of the World), temperature and rainfall (from University of Delaware) and a dummy variable equal to one if the grid cell contains any natural resource deposit interacted with a composite resource price index (natural resource data on petroleum and diamonds from PRIO[24], data on other natural resources from MRDS[25], price index from IMF – the variable is PALLFNF_Index). The population data is interpolated, since it is only available at 5-year intervals, and the climate data unfortunately ends in 2008 – as only an imperfect way to extend the data I assume that temperature and precipitation is identical in 2009 and 2010 to 2008. Making use of this localized climate data also permits the separate testing of climate-income relationships at the subnational level, as opposed to the country level as in Dell, Jones and Olken (2012). Though I leave this for future work.

[24] See http://www.prio.no/Data/Geographical-and-Resource-Datasets/.

[25] See http://tin.er.usgs.gov/mrds/.

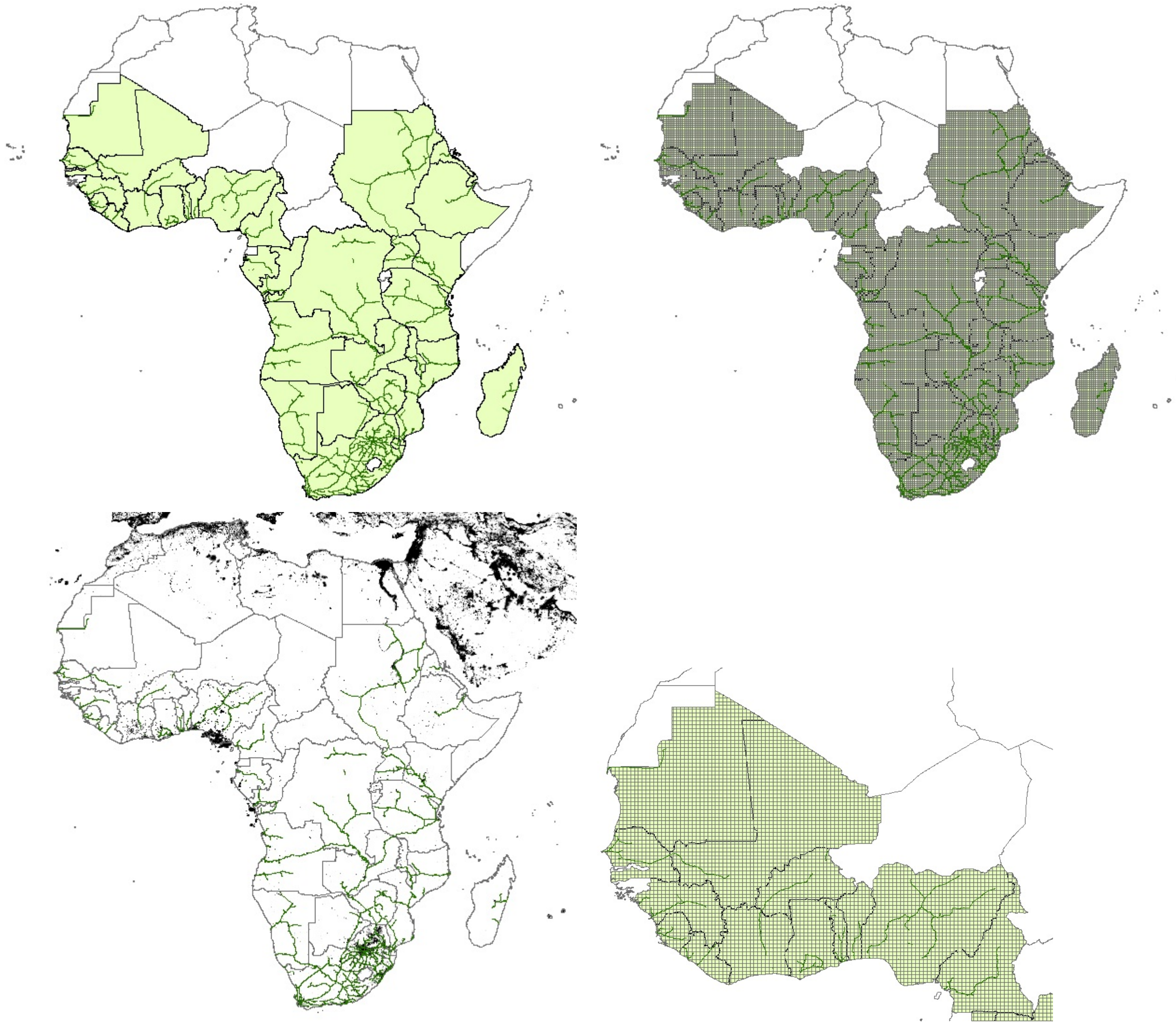


Figure 2: African Rail, Grid and Lights

5.1 Econometric Specification

The preferred fixed effects estimation is

$$y_{it} = \alpha_i + \alpha_{jt} + \Sigma_{j=20,40,60,80} \beta_j rail\left[j\right]_{it} + \Sigma_{j=20,40,60,80} \gamma_j \left(rail\left[j\right]_{it} \times priv_{it}\right) + \varphi X_{it} + \mu (res_i \times price_t) + \varepsilon_{it}$$

where i indicates grid cells, y is $ln(0.01 + lights)$, $rail\left[j\right]$ is a dummy variable equal to one if the cell centroid is $< j$ and $> j - 20$ kilometres from the nearest line, $priv$ is a dummy equal to one if the nearest line is privately run, X is a vector of controls (population and climate variables), res_i is a dummy variable equal to one if the grid cell contains natural resources[26], $price_t$ is the composite resource price index, α_i are grid cell fixed effects and α_{jt} are country-year dummies, where j indexes countries. The coefficients of most interest are $\gamma_j \forall j$ since they reflect the differential impact of privatized as opposed to state-run rail on local economic activity. β_j are essentially nuisance parameters – they are identified only from the very slight panel dimension in that one new line was built in 1999 in Zimbabwe[27].

Within the fixed effects specification I test for common trends by creating new interaction terms between $rail\,[j]$ (only for $j = 20, 40$) and $t-1$, $t-2$ etc. The latter are dummy variables set equal to one only for privatized lines in the first, second, third etc. years prior to privatization (I go as far back as 16 years, though the identification comes from fewer countries the further I go). These interactions act as placebo checks – testing for any 'ghost' impact of privatization before the treatment has begun. Similarly, I add interaction terms with each year following privatization to investigate dynamics – in particular whether impacts, if they exist, are 'level' or 'growth' effects, hence the illustrative model in Section 3.3. Standard errors are corrected for clustering and auto-correlation by clustering at the district level[28].

6 Results

The results are shown in the Appendix in Tables 2, 3 and 4, corresponding to baseline estimates, robustness and trend analysis.

Table 2 shows a positive and localized impact of privatization robust to the inclusion of year dummies, country-specific time trends, country-year dummies and controls. The coefficient of most interest, the <20km interaction, attenuates only slightly as fixed effects and controls are added, suggesting a little omitted variable bias to begin with. The other interactions are never statistically significant, but the point estimates roughly decline in distance from the railway line as expected. It seems the effects only extend 20km from the railway line (in each direction). The negative sign on the 60-80km interaction in 2.2-2.4 hints at displacement effects, i.e. areas closest to the line benefitting at the partial expense of areas further away. But given that the magnitude of the point estimate is so small and the coefficient insignificant, the evidence here suggests displacement effects are weak.

The population control is not significant, though of the expected sign. The lack of a significant coefficient is somewhat puzzling, but is probably explained by the lack of variation

[26] Ideally there should be a panel dimension to this variable, but data on the date of discoveries of natural resources is scant – so I use only the cross-section. The approach here is then an imperfect approximation to natural resource wealth.

[27] In other studies on the impact of railways, these would of course be the coefficients of interest.

[28] I use tools in ArcGIS to spatially join to each grid-cell the name of the district it is closest to.

in the source data – Gridded Population of the World data is only available at 5-year intervals, and the more recent data (2005 and 2010) is forecast estimates. For these reasons, it is difficult to interpret the results when controlling for population as the impact on per capita economic activity. I drop this control from the subsequent analysis. As the theory section implied, the focus will be on aggregate consumption and income, rather than a per capita interpretation. The climate variables are also unimportant, but the coefficient on natural resource wealth is highly significant and positive. This lends more support to the claim throughout that the lights data is reflective of local incomes.

Table 3 shows various robustness checks to the core result. Each column gives a slight variant of the baseline regression in column 4 of Table 2. Regression 3.1 shows the core result is robust to excluding certain 'problem' countries: I exclude countries that may be biasing the results due to civil war/closed railways. These countries are Angola, DRC, Eritrea, Liberia, Sierra Leone and Togo[29]. 3.2 shows the standard errors to be relatively unaffected by clustering by the ID of the nearest rail line, as opposed to district-level. This is arguably a more appropriate approach given that the treatment is at the railway-line level, rather than at district-level.

In 3.3 I drop continuously unlit grid cells and those with zero population[30]. The key result holds, though the coefficient is smaller. In 3.4 I drop *all* unlit cells – now if anything there appears to be a negative impact of privatization. Combined with the other results, this suggests that the positive impact we see comes from previously unlit grid cells becoming lit, as opposed to existing lit cells getting brighter. The evidence suggests privatization spurred new economic activity close to lines, rather than the growth of existing centres of activity.

In the remaining columns I simplify things by restricting the sample only to grid cells within some distance of a railway line. Disconcertingly, the coefficient falls a little, and in the final column, goes negative and insignificant. It is not clear why the result doesn't survive this particular robustness check – further exploration is needed.

In Figures 2 to 5, I graph the results from regressions using year interactions. The green line plots point estimates, the dashed lines give the confidence intervals. Figures 2 and 4 show the year-by-year effects from 15 years before privatization to 15 years after for areas <20km from a line and those 20-40km from a line. On face value, Figure 2 suggests a concern that areas to be privatized were already 'catching up' over the period starting 15 or so years prior to privatization. But it is important to recall that the further we go back, and the further we go forward, the fewer countries are left to identify the coefficient (e.g. the identification

[29]See "Reason to Omit?" column in Table 1 for more information

[30]I do this as an attempt to address the concern of the significant bottom coding of the lights variable at zero (before transforming to ln(0.01 + lights)). The resultant sample size is less than half that previously (showing the sheer amount of bottom coding in Africa).

of $rail\,[20] \times (t-15)$ comes only from grid cells with the nearest railway privatized at some point, that have data 15 years prior to that privatization). Since much of the later and earlier years are driven by such a small proportion of the sample, I offer the following (admittedly ad-hoc) suggestion: only consider the coefficients identified by at least 50% of the overall grid-cell years experiencing privatization. Figures 3 and 5 then restrict to only the coefficients identified by at least 50% of treated areas.

In Figure 3 we can see that the confidence intervals contain zero for much of the period prior to privatization, whilst following privatization, the confidence intervals never contain zero. In a strict statistical sense, we can see that parallel trends fails, but in a way that is supportive of a positive impact of privatization. Since the coefficients are positive and significant around seven years before, and roughly falling thereafter (until t), it seems that areas to be privatized were growing faster some years before privatization, but in the run-up to privatization, conditional growth rates converged across the 'treatment' and 'control' groups. The act of privatization appears to have then caused renewed divergence.

The first four years of privatization show a positive, significant and increasing impact on economic activity. The increasing trend is consistent with privatization inducing investment by firms (as in the model in Section 3.3) or with new railway operators improving the quality of the line over time.

Figure 5 shows the same graph for areas within 20-40km of a railway line. The effects are insignificant throughout – in some sense this is in itself a placebo test. Parallel trends passes resoundingly for these areas – for the full 15 years prior to privatization, there were no statistical differences in lights (conditional on controls and fixed effects) between areas to be privatized and areas never privatized.

Overall, the results lend credence to the view that privatization had a positive, but local, impact on economic activity. The sensitivity of results to dropping areas distant from railways is concerning and will be explored in future work. Endogeneity is another concern, but several complementary pieces of information suggest a causal interpretation is not unfair: the evidence on pre-trends, the anecdotal evidence that privatization was often motivated by donor pressure and experienced delays[31], and the robustness to the resource wealth control and various fixed effects.

7 Conclusion

Africa has a dis-functioning rail network by any standard: it is sparse, out-dated and in parts not operational. Policy-makers have a mammoth task to revive it, if they choose to do so. The

[31] These arguments I hope to explore more.

World Bank estimates the investment backlog to be $3 billion and puts annual expenditure needs at $200 million. Proposals to expand the network to be truly trans-African would cost far, far more – upwards of $40 billion. Is there hope for African rail?

The evidence here suggests that ongoing privatization efforts since the mid-1990s have been a step in the right direction. I find that privatization has a positive, significant and localized impact on economic activity, proxied by light density measured by satellites. The effect looks to have increased over time, and placebo tests using data prior to privatization suggest the effects are causal – there is no evidence that areas to be privatized were already growing faster prior to privatization.

Whilst promising, the results here give evidence on only one dimension of economic activity, with little to say about mechanisms. To remedy this I hope in future work to use the survey evidence in four waves of Afrobarometer data from 1999-2008. The survey includes questions on economic conditions (useful to corroborate the result on lights) as well as questions on support for the state (an interesting outcome to explore in the context of privatization).

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Appendix

TABLE 1: African Rail Facts

Country	Ownership	Privatization Date (if known)	Privatization Year (coded)	Reason to Omit?
Angola	Public			Angolan civil war 1975-2002 damaged railways*
Benin	Public			
Botswana	Public			
Burkina Faso	All Private	August, 1995	1995	
Cameroon	All Private		1999	
Congo, DRC	Most Private		1995-7, 2008	Civil war prevented rail from operating 1998-2004*
Congo, Rep. Of	Public			
Djibouti	Public			
Eritrea	Public			Closed between 1975 and 2003 due to civil war*
Ethiopia	Public			
Gabon	All Private		1999	
Ghana	Public			
Guinea	Part Private		Throughout	
Ivory Coast	All Private	August, 1995	1995	
Kenya	Most Private	November, 2006	2007	Rail affected by Kenyan crisis 2007-2008
Liberia	All Private		Throughout	Proparco (2011) implies all lines have closed*
Madagascar	Most Private		2003	
Malawi	All Private	December, 1999	2000	
Mali	All Private	October, 2003	2004	
Mauritania	Public			
Mozambique	Most Private		2005	
Namibia	Public			
Nigeria	Part Private		Throughout	
Senegal	Most Private	October, 2003	2004	
Sierra Leone	Part Private		Throughout	Most lines ceased operating in 1974, according to some sources*
South Africa	Part Private		Throughout	An outlier in terms of income and size of railway network*
Sudan	Public			
Swaziland	Public			
Tanzania	Most Private	October, 2007 - February, 2011	2008-2010	
Togo	Part Private		1995-2001, 2002	No trains have run for many years according to some sources*
Uganda	All Private	November, 2006	2007	Also affected by Kenyan crisis 2007-2008 since Uganda is landlocked
Zambia	Part Private	February, 2003	2003	
Zimbabwe	Part Private	July 15, 1999	1999	

TABLE 2: Baseline

Dep Var: ln(0.01 + Lights)	2.1	2.2	2.3	2.4
<20km*Priv	0.135***	0.134***	0.124***	0.119***
	(0.0246)	(0.0214)	(0.0207)	(0.0200)
20-40km*Priv	0.0257	0.0205	0.0191	0.0113
	(0.0218)	(0.0195)	(0.0193)	(0.0184)
40-60km*Priv	0.0283	0.0213	0.0237	0.0128
	(0.0267)	(0.0216)	(0.0222)	(0.0200)
60-80km*Priv	0.00130	-0.00564	-0.00449	-0.0148
	(0.0258)	(0.0210)	(0.0203)	(0.0183)
ln(0.01 + Population)			0.00618	
			(0.00813)	
Temperature			-0.00686	0.00431
			(0.00551)	(0.00657)
Rainfall			1.97e-05	5.00e-05
			(0.000114)	(0.000156)
Resource*Price			0.00165***	0.00189***
			(0.000497)	(0.000479)
Constant	-4.141***	-4.380***	-4.256***	-4.263***
	(0.00658)	(0.0143)	(0.141)	(0.163)
Observations	350,835	350,835	345,306	345,857
R-squared	0.045	0.071	0.074	0.104
Number of Cells	18,465	18,465	18,174	18,203
Year Effects	Y	Y	Y	
Country Time Trends		Y	Y	
Country-Year Effects				Y

Standard errors (in parentheses) clustered at district-level throughout.
Coefficients on distance to rail (<20, 20-40, 40-60, 60-80) not shown.
*** p<0.01, ** p<0.05, * p<0.1

TABLE 3: Robustness

Variants on 2.4	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8
	Dropped Countries	Cluster by Rail ID	Drop Cont. Unlit and Zero Pop.	Drop All Unlit and Zero Pop.	<80km	<60km	<40km	<20km
<20km*Priv	0.132***	0.119***	0.0614**	-0.0297	0.0990***	0.0831***	0.0483**	-0.0160
	(0.0259)	(0.0216)	(0.0299)	(0.0353)	(0.0213)	(0.0214)	(0.0240)	(0.0279)
20-40km*Priv	0.00647	0.0113	-0.0232	-0.0944*	-0.00987	-0.0266	-0.0614**	
	(0.0226)	(0.0192)	(0.0352)	(0.0519)	(0.0226)	(0.0235)	(0.0273)	
40-60km*Priv	0.0295	0.0128	0.0180	-0.0175	-0.00847	-0.0261		
	(0.0256)	(0.0240)	(0.0442)	(0.0564)	(0.0230)	(0.0233)		
60-80km*Priv	-0.0113	-0.0148	-0.0353	0.0521	-0.0365*			
	(0.0250)	(0.0185)	(0.0441)	(0.0575)	(0.0217)			
Observations	275,272	345,857	134,844	61,976	119,255	92,860	62,790	31,629
R-squared	0.111	0.104	0.186	0.328	0.108	0.120	0.144	0.200
Number of Cells	14,488	18,203	7,100	7,093	6,281	4,894	3,311	1,668
Cluster	District	Nearest Line	District	District	District	District	District	District
Year Effects					Y	Y	Y	Y
Country Time Trends					Y	Y	Y	Y
Country-Year Effects	Y	Y	Y	Y				

Temperature, Rainfall, Resource*Price, Constant and distance to rail coefficients not shown. Standard errors clustered at district-level unless stated otherwise. *** p<0.01, ** p<0.05, * p<0.1.

Pre- and Post-trends

I interact with each year separately (omitting the year immediately before privatization) to test for 'placebo' effects pre-privatization and growth vs. level effects post-privatization.

FIGURE 2: <20km Effects

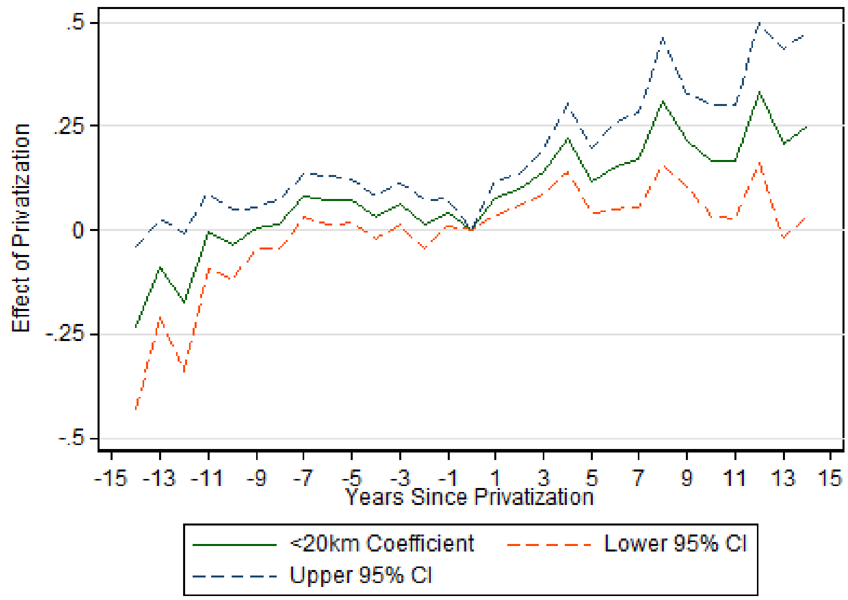

FIGURE 3: <20km Effects Driven by at Least 50% of Treated Areas

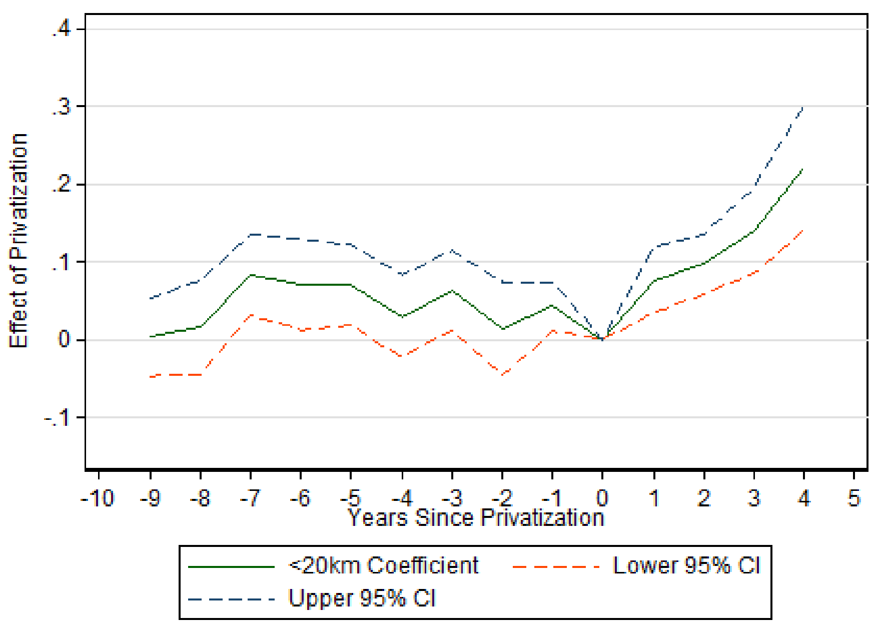

FIGURE 4: 20-40km Effects

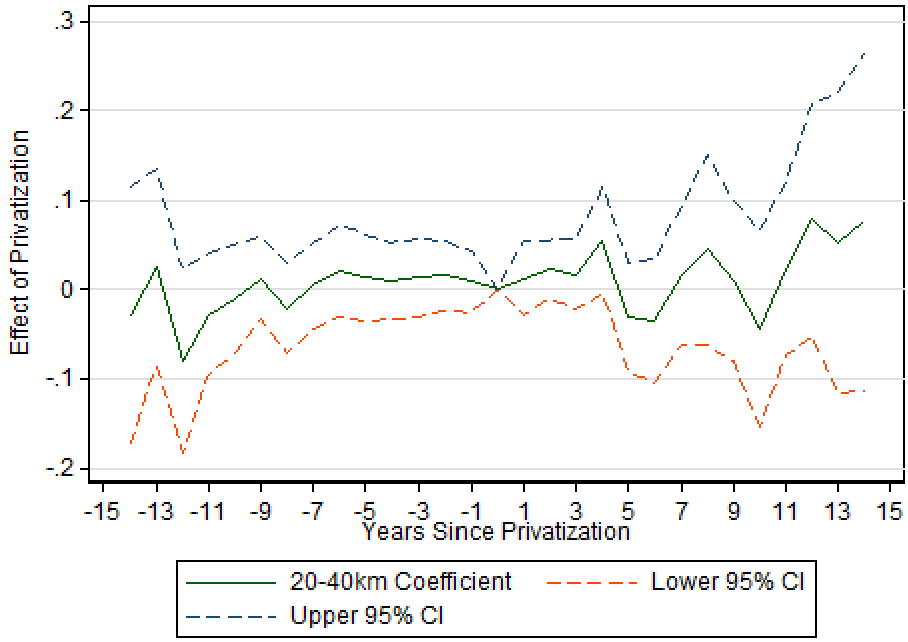

FIGURE 5: 20-40km Effects Driven by at Least 50% of Treated Areas