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Evaluating the impact of infrastructure development

Case study of the Konkan Railway in India

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Transportation

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Summary

The Konkan Railway is one of the biggest railway construction endeavour in independent India. Operational since 1998, the railway stretches over 760 km along the Konkan region of three West Indian states of Maharashtra, Goa and Karnataka – a hitherto backward region, characterized by outmigration for employment and education. However, the region is also known to be ecologically sensitive, which is why this infrastructure project was frequently contested for its potential impacts on the local ecosystem. The present study is an attempt towards providing empirical evidence and exploring causal mechanisms of the socioeconomic and environmental impacts of the Konkan Railway as a real-world large-scale infrastructure project.

We employ a theory-based evaluation approach that relies on a plurality of techniques, a combination of quantitative and qualitative strategies across disciplines. Specifically, we apply different quasi-experimental techniques at the level of intermediate outcomes and impacts in the short and longer term, using census and satellite data and information retrieved from document and archival analyses and interviews. The evaluation questions this study seeks to answer are: What are the socioeconomic impacts of the Konkan Railway such as on population and workforce composition? What has been the effect of Konkan Railway on the land use pattern in the region? Have the stated project objectives of the Konkan Railway been achieved?

One of the key learnings from the analysis of the operating performance of Konkan Railway was that it was subjected to a variety of political and regulatory risks and risks posed by changes in overall macro-economic environment. The available documentation suggests that the traffic projection study for the Konkan Railway did not account for risks and uncertainties, leading to overestimations of projected freight traffic. It also illustrates how factors external to project operation create uncertainties in the benefits to be derived from infrastructure projects. Importantly, the demand for transport is a derived demand, that is, demand for transport occurs as a result of demand from other sectors. In the case of the Konkan Railway, regulatory uncertainties, changing macro-economic conditions and the fall in output of several industrial units affected the demand for freight services. The projections themselves seem to have been too optimistic, as well. The findings thus highlight the importance of paying closer attention to accurate forecasting and the implementation and regular updating of risk analysis for infrastructure projects.

Passenger traffic on the other hand registered a healthy growth rate over the years. Savings in cost on account of subsidized train fare and time have made it the preferred mode of transport in the region over the highway. It emerged from the key informant analysis that over and above the monetary factor, for the travellers the railways provide a tangibly different experience in terms of comfort, on board-facilities and safety which buses or an expanded highway network may not be able to match. Though the railway and highway act more in complementary ways, the highway competes with the railway when the cost of the first mile and last mile transport from the railway station is higher than the train fares. This helps us draw important policy recommendations as to how the railway and the highway can be made to work in more complementary ways. Instead of working as a linear mode of transport from station to station, the railway and the highway could be made to work in a manner that it forms an integrated transport system for travel within and outside the region, by measures such as having more buses ferrying

passengers to and from the station, a common ticketing system and with schedules which match the train timings. This can help the railways to penetrate deeper into the districts and neighbouring districts.

Moreover, contrary to the initial expectations that the Konkan Railway project will usher in an era of industrial development and change the migration-prone character of the economy by creating job opportunities in the project influence area, our interaction with the key informants suggest that the Konkan Railway has not contributed much to industrial development. Another important conclusion of the exercise was that the establishment of a new transport infrastructure is by itself unlikely to generate new industrial investments, especially in lagging regions. An important lesson that can be drawn from this is that railways might lead to industrial development and consequently generate freight for itself, under the following non-exhaustive list of conditions: state governments provide a proper climate for industrial investment; investors take advantage of the railway line; suitable accompanying infrastructure such as ports; and public participation in decision making in setting up industries to manage public resistance and delays. On the one hand, without these conditions being fulfilled, generating freight to meet the actual projections is unlikely. On the other hand, even with these conditions being fulfilled increased freight is likely but not certain. Transport infrastructure may therefore be a necessary but not sufficient condition for changing the geography of industrial production.

The key informant interviews and other steps in the analysis exposed that the Konkan Railway was mostly experienced by the people as having improved the connectivity within and between the states and with the rest of the country, most importantly, with Mumbai, the regional economic powerhouse located about 100km north of the northern terminus station on the Konkan Railway. It has amplified the already existing pattern of travel in the region to Mumbai in this region, where migration plays an important role as a livelihood diversification and income enhancement strategy. At the same time, it has enhanced the available choice of destinations by connecting the region to the rest of the country, namely Gujarat, New Delhi, and Kerala.

In our quasi-experimental analysis, we found that the Konkan Railway had a positive effect on population sizes in the villages and towns in the proximity of railway stations. Further the percentage of male main workers (defined as those who work for more than six months a year) to total workers declined and the sex ratio between females and males increased. It seems plausible to conclude from this that the railway access has reinforced the pre-existing pattern of high levels of male migration. The improved accessibility makes it easier to undertake frequent trips, thereby helping in maintaining social links with the place of origin. Our findings are in line with those of studies from developing countries that find that enhanced transport connectivity has an important role to play in the decision to migrate or to commute to work.

In addition to an increase in population, we also find an increase in crude workforce participation rate driven by an increase in marginal workers (defined as those who work for less than six months a year) closer to the station. We also found an increase in other (main) workers defined as those who engage in non-agricultural activities for more than six months a year and insignificant results for cultivators and agricultural labour for villages and towns in close proximity of the railway station. These results led us to conclude that the Konkan Railway has encouraged diversification into non-agricultural economic activities and also of workplaces by making it easier to access employment opportunities via daily commutes between rural and urban areas and seasonal migration. The socioeconomic and employment profiles of the seasonal and commuting workers are an interesting subject of further research. Deeper analyses of economic survey data may also shed more light on supply-side aspects of outcomes regarding the labour market and economic activities.

We only find insignificant changes in forest cover and water bodies in close proximity to the railway station. The analysis could hence not substantiate the concerns raised during the time of the construction of the Konkan Railway about the environmental degradation it might bring in its wake, at least not at a larger scale.

While, the literature from the fields of economic geography, migration, and labour economics acknowledges the role played by transport in labour mobility, this study is among the few that helps in quantifying the changes in population and workforce composition in response to an improved transport infrastructure. This has important implications as far as investment in transport is concerned. The impact evaluation raises pertinent questions such as the implications of improved transport network for migration – whether long-term or seasonal – and for daily commuting to work from rural to urban areas. By incorporating the perspective that migration is used as a livelihood diversification and income enhancing strategy by households and commuting as a strategy for diversification of workplace, our study allows to derive some conclusions related to labour market outcomes and regional employment and development. For development planners and policy makers, the study encourages considering the impact of transport infrastructure on geographic labour mobility and labour market outcomes in the sending and receiving regions. While planning investment it encourages transport and development planners in both sending and receiving regions to take into consideration how transport infrastructure helps in diversifying of workplace and economic activities. Another important area of further research is whether improved transport connectivity encourages people to undertake rural-urban daily rather than migrate. The findings from this study can help transport ministries and urban planners to better understand its role in present developing country circumstances and allow them to make more informed decisions regarding policy and investment in railways.

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Abbreviations

CAGR	Cumulative Average Growth Rate
CWPR	Crude Workforce Participation Rate
DEM	Digital Elevation Models
DID	Difference-in-differences
GDP	Gross Domestic Product
GIS	Geographic Information System
KRCL	Konkan Railway Corporation Limited
LULC	Land use/land cover
NSSO	National Sample Survey Organization
OW	Other Workers
PP	Percentage Points
USGS	United States Geological Survey

1. Introduction

Developing countries still face a large transport infrastructure gap. The transport investments they make today will lock in development patterns for decades to come. India needs efficient and sustainable transport infrastructure which can meet its developmental imperatives and help to provide a better quality of life for its people as well as aid in transitioning to a sustainable and low-carbon future. However, post-independence India has had its share of controversies around large transport projects such as railways, highways and airports, which have pitted environmental preservation against development concerns. On the one hand, such projects come with promises of substantial socioeconomic benefits in terms of economic growth, improved incomes and quality of life, increased livelihood opportunities, regional development and national integration. On the other hand, local objections against them claim environmental degradation, displacement, loss of livelihood, and disruption of the way of life of the affected community.

Such controversies are especially prevalent in the Western Ghats region in India. Western Ghats is a chain of mountains that run parallel to the western coast of India on a stretch of 1600 km. The region is globally recognized for its high level of biodiversity, endemism, and unique geomorphic features with unique biophysical and ecological processes. The Indian government successively commissioned and released two reports by different expert panels for making recommendations for the conservation, protection and rejuvenation of the Western Ghats region. Though the development and conservation of the Western Ghats region has gained prominence in the agenda of the Central and State governments. However, there is a dearth of empirical evidence on the long-term impact of the large infrastructure projects already operating in the region, which makes it difficult for policy makers and stakeholders to make decisions regarding future developmental activities in the Western Ghats.

The paucity of evidence on the impact of large infrastructure projects is however a much larger phenomenon. Notwithstanding the recent surge in impact evaluations, studies on infrastructure interventions and its effect on indicators of development and economic growth remain scarce, especially those that can hardly be scaled and thus involve significant public investment such as dams, highways, railways, airports and ports. Moreover, contested infrastructure projects continue to be referred in subsequent debates about environmental impacts. However, they are rarely systematically studied later on for their long-term impact. This creates obstacles to policy makers and stakeholders when it comes to planning future developmental activities.

This study attempts to contribute to the methodological and empirical literature on the impact of large infrastructure projects in general and in the context of the Western Ghats region in India in particular. The case study, we use is the Konkan Railway project built through the Western Ghats between 1991-1998. Just as for a number of other large-scale infrastructure projects Konkan Railway has been the subject of controversies in which environmental and development concerns have been pitted against each other.

Most existing studies study the impact of historic railway networks. Historically, since the mid-19th century, railway lines have played a key role in improving accessibility in many parts of the world. However, since the mid-20th century, the role of the rail network has been replaced to a large extent by the use of cars and the expansion of road networks. Railways constitute a shrinking share of freight transport in many developing countries as well, where road transport is preferred as it is more penetrative than rail services and more flexible as it can quickly adjust to changes in demand and unforeseen circumstances.

Undertaking an analysis of the impact on the level of socioeconomic activity, the environment and people's well-being of a railway venture completed in the final decade of the 20th century will allow transport ministries and urban planners to better understand its role in present developing country circumstances and allow them to make more informed decisions regarding policy and investment in railways. Railways, especially High Speed Railways, are being promoted worldwide as a more environmentally friendly alternative to move passengers and freight.

We employ a theory-based evaluation approach that relies on a plurality of techniques, a combination of quantitative and qualitative strategies and an interdisciplinary approach tailored to these questions to study the impact of Konkan Railway which we characterize as a complex intervention. Specifically, we apply different quasi-experimental techniques at the level of intermediate and ultimate outcome and impact indicators for shorter and longer term, using census and satellite data and information retrieved from document and archival analyses and interviews. We draw on insights from the discipline of economics, sociology and geography in making sense of large infrastructure projects and their impacts.

The rest of the report proceeds as follows: We begin with identifying the main evaluation approaches and methodological challenges faced in evaluating large infrastructure projects. We then describe our research questions and our theory of change for the impact, keeping in mind the complex nature of the intervention. A description of the evaluation design follows. The evaluation design is further divided into various steps and the methodology and data sources of each of these are described in detail: archival research; descriptive analysis of the intermediate outcomes; key informant interviews; quasi-experimental design and land use change evaluation design. We then describe the study area, the Konkan region and the historical transport scenario in the region. The main findings from the different steps in the analysis follows, followed by conclusion and policy implications.

2. The scarce evidence on effects of infrastructure projects – main evaluation approaches and challenges[1]

The development literature generally regards the availability of and access to infrastructure as integral to economic development, improvements in quality of life and well-being of a society. Transport infrastructure, specifically, is thought to have the potential to facilitate economic growth and alter livelihood opportunities, including changes in rural-urban dynamics that facilitate the agglomeration process. A recent World Bank report notes that South Asia requires substantial investments in infrastructure such as railways, roads, power, telecommunications, water supply and sanitation "not only to ensure basic service delivery and enhance the quality of life of its

[1] This section borrows from Jaiswal and Bensch (2018)

growing population, but also to avoid a possible binding constraint on economic growth"(Andrés, Biller and Herrera Dappe 2013: 1).

However, despite this widespread belief in the importance of infrastructure, empirical evidence of its effect on indicators of development and economic growth remains limited. Notwithstanding the recent surge in impact evaluations, studies of infrastructure interventions remain scarce, as these interventions generally fall under what White calls small n interventions, where n is the number of possible observations at the level of assignment of the intervention (White 2011). A small number of cases to be examined makes it impracticable to adopt quantitative experimental or quasi-experimental evaluation approaches that serve to attribute changes to the intervention and not to other factors.

The paucity of evidence is even more regrettable as the role of dams in alleviating poverty is hotly debated, to give just one example. For proponents, dams are synonymous with development and economic progress, whereas opponents worry about the detrimental effects on displaced communities, livelihoods and ecology. Among the few studying dam construction effects, Duflo and Pande (2007) find that large dams in India have benefitted downstream populations. However, those living in the districts in which the dams were built did not see any agricultural productivity gains, but rather suffered from increases in the volatility of agricultural production and worsening of living standards. The authors suggest that this could be because neither market actors nor state institutions have taken actions to alleviate the adverse distributional impacts of dam construction.

When it comes to railway infrastructure, Donaldson (2010) provides evidence that the railroads built in colonial India significantly reduced trade costs and stimulated inter-state trade. Further studies exploit data from the 19th century to assess railway access impacts. Donaldson and Hornbeck, find that railroad network expansion between 1870 and 1890 improved market access for counties in the United States of America (USA) and thereby increased agricultural land values (Donaldson and Hornbeck 2016). Using county-level data from the USA spanning the period 1850 to 1870, Atack et al., (2010) argue that railroads increase competition among firms by increasing market size. This fostered the productivity-increasing division of labour of firms, which in turn expanded in size and formed the nucleus around which American manufacturing rose. In a related study focusing on the American Midwest, the authors observe only a small positive effect of rail access on population density but a large positive impact on urbanization.

Among the studies which exploit more contemporary data to estimate the impact of railways, examining the case of South Africa, Sequeira (2011) finds that the railway had only a negligible impact on transportation costs of firms. One reason for this limited impact, she suggests, could be the monopolistic practices in railway management in the form of distorted pricing practices and restrictive access to rail slots. Banerjee et al. (2012) run estimations on the long-run effects of access to transportation networks on regional economic outcomes between 1986 and 2003, and find only small positive causal effect on per capita GDP levels across sectors, a result that may be attributed to a lack of factor mobility in the Chinese setting. In contrast, Wang and Wu (2015) find that Qingzang railway (Qinghai-Tibet railway), had a significant causal effect on the economic development for the undeveloped regions. It increased the GDP per capita of the railway counties by about 33 per cent, mainly by having a positive effect on the manufacturing industry that is likely to compete in the national market, while the agriculture and service industry which are likely to compete in the regional market were hardly affected by the new railway.

The effects of highway infrastructure is increasingly studied and yielded similar, mostly trade-related effects in terms of reduced transportation cost and inventories (Datta 2012; Michaels 2008; Chandra and Thompson 2000). These studies, however, also show displacement effects in neighbouring regions.

Reasons for the sparsity of literature on large infrastructure projects are manifold. First, the researcher is usually faced with a small n setup, i.e. a small number of units of assignment (railways, ports, etc.) and a small reservoir of potential comparison units, with the result that quantitative tests of statistical differences in outcomes are often not feasible (White and Phillips 2012). Second, large and distant spillovers of infrastructure interventions render the use of evaluation approaches difficult (Estache 2010). Third, large infrastructure projects do not easily lend themselves to experimental techniques, since – for political reasons – they can hardly be randomly assigned. Fourth, the alternative of quasi-experimental methods is often fraught with the methodological challenge of the likely endogeneity of the placement of these projects. This means that initial conditions are likely to determine project placement, as well as influence the subsequent growth path and prospects of the intervention area (Jalan and Ravallion 1998a). This makes it difficult to answer the causal question of interest, i.e. whether the better outcomes of the area were due to the infrastructure (Fishlow and Fogel 1971), (Fishlow and Fogel 1971; Fishlow 1965). Put differently, decisions regarding the planning, implementation and operation of large infrastructure projects are a negotiated outcome between project developers, policymakers and citizens, which somewhat counters the idea of an exogenous intervention (see also Pawson, 2006).

In order to tackle the main methodological issue of endogenous placement and thus to aid identification, evaluators of infrastructure projects mainly use instruments or natural experiments. For example, Wang and Wu (2015), argue that the newly constructed Qingzang railway forms a natural experiment based on two reasons. Firstly, as it did not result from local economic development as it connects two underdeveloped provinces of China. Secondly, although the local government and residents welcomed the project, the project was mainly promoted and financed by the central government and the choice of route was mainly determined by technical and cost concerns. Other studies include, Chandra and Thompson (2000) who argue that interstate highways are typically built to connect two metropolitan areas, and thereby happen to cross many nonmetropolitan counties. As such, if the route of the highway was not changed in order to include some intermediate cities or counties and exclude others based on factors correlated with the outcome of interest, then the highway can be considered as an “exogenous event” or quasi-random shock to the areas which happen to fall en-route. A similar identification strategy has been used by Datta (2012) to study the impact of highways. Relying on this identification strategy, Chandra and Thompson (2000) used a fixed-effects model and Datta (2012) a difference-in-differences model. Another highway evaluation study, Michaels, constructed two different Instrumental Variables (IVs) based on historic highway plans and the direction to the nearest city. IVs have also been the preferred approach for most other studies: Duflo and Pande (2007) use river gradient to instrument for the placement of dams based on the fact that the gradient at which the river flows affects the ease of dam construction. In the case of railway infrastructure projects, Atack et al. (2010) construct an IV for the distance to a railroad based on the straight line between the start and end points of the railway line. The rationale is that if the railway was built solely to connect the two points, it would be built on a straight line, representing the shortest distance between them. Similarly, Faber (2014) uses both a straight-line instrument as well as estimates of least costly construction paths using remote sensing data on land cover and elevation in combination with an optimal route algorithm. In other words, the authors attempt to find a credible exogenous variation in causes of infrastructure access that predicts infrastructure access but does not have a direct effect on the outcome in question. IVs have also been used by Atack et al. (2011), Banerjee et al. (2012) and Hornung (2015) in their work on impacts of railways.

The available literature on infrastructure impacts, which has been selectively reviewed here, reflects tremendous advancements in approaches to dealing with measurement challenges inherent in the evaluation of large infrastructure projects. To contribute to this growing literature, we use the case study of the Konkan Railway project from India, which we describe in the next section.

3. Intervention

3.1 Transport Scenario in the Konkan region before the Konkan Railway

The first proposal for a railway line in the Konkan region was mooted as early as 1894. The project was deemed financially unviable by the British colonial government given the difficult terrain of the region which posed considerable engineering challenges. The two rail head extremities in Maharashtra and Karnataka therefore remained separated by a gap of 760 kilometres and continued to be served only by non-rail routes, namely road and coastal shipping. By the end of the nineteenth century, there were regular steamship services that would call at various small ports along the Konkan coast. Road transport remained poor improving slightly by 1920s. It was not until the development of a proper bus network post-independence that road transport competed with water transport. Iversen and Ghorpade (2011) record that in the mid-1930’s, a migrant worker's journey from Udupi to Mumbai would be by coastal steamer or overland; the latter would be arduous, involve many river crossings and take about three days to complete. Between 1960’s and 1970’s, the National Highway (NH) 17 (currently renumbered to NH 66) was completed. It runs north to south along the western coast roughly parallel to the Western Ghats. This somewhat improved the transport situation in the region. By 1980’s, due to a number of reasons, chiefly the mounting losses of shipping companies and competition faced by the improved road transport, the ship services along the west coast were discontinued. Demand for passenger movement in the 1980’s was therefore being met by public and private buses plying on NH 17 or via a long circuitous rail route which required changing trains. The NH 17 was a narrow single lane highway through the hilly and treacherous terrain. The movement of vehicles on this road was hazardous, accident-prone, time-consuming, and would worsen during the monsoon season. Accidents on NH 17 were quite common and continue to be so (See for example Bhuyan 2016). The railway route on the other hand was a metre gauge railway line which connected Goa to the hinterlands of Karnataka and was the only rail link in the region, till the Konkan Railway started services. To continue the journey towards Mumbai or to the South, would entail changing trains at the Goa-Karnataka border. Depending on the schedule of the trains, the journey could take up two to three days.

3.2 The Konkan Railway

Given the inadequate transport situation and the region's historic link to Mumbai, the need for a railway line connecting Mumbai to Mangalore was acutely felt and demanded by the people of the Konkan region, with frequent mentions of this being a "missing link" and a "dream project". Many proposals were advanced between 1945 and 1970's, however financial and engineering obstacles continued to frustrate all endeavours. The project gained political momentum when two prominent leaders from the Konkan region, George Fernandes and Madhu Dandavate (from Karnataka and Maharashtra, respectively) became the Minister of Railways and the Finance Minister, in the short-lived Janta Dal government from 1989 to 1990. Due to the huge financial outlay, the Government of India set up the Konkan Railway Corporation Limited (KRCL) in 1990 as a public sector undertaking under the Ministry of Railways to execute the project and raise the bulk of the finances from the market. In a first, as opposed to other railway projects which were financed by the Ministry of Railways, KRCL saw the financial participation of four states (Maharashtra, Goa, Karnataka and Kerala) and the Indian Railway. It was entrusted with the task of raising the rest of the funds from the market and constructing the Konkan Railway as single line broad gauge route on a Build Operate Transfer (BOT) basis becoming the first such public infrastructure project in India to be executed by a separate entity and on a BOT mode. Final surveys and construction began soon after. While the complete Konkan Railway line of 760 km became operational in January 1998, from 1993 onwards the Railway was opened up for traffic in phases from each end. Out of the total length of the line, 382km passes through the State of Maharashtra, 105km through Goa and 273km through Karnataka. The project cost Rs. 3350 crores and was completed nearly three years after its original scheduled date with a 222 per cent cost over-run. The cost overruns are mainly due to inflation, delays caused by the technical problems encountered in digging tunnels through soft soil and halting of work for nine months due to court litigations and environmental protests.

3.2.1 Distance and time savings

Konkan Railway significantly reduced the distance and travel time for various destinations to and fro from northern, central and western India to southern India. ***Table 1*** compares the length of the railway route and time taken for various origin-destination pairs before and after the Konkan Railway started operations. ***Table 4*** does the same for rail vs road.

Table 1: Distance and Travel Time for Railway Routes Before and After the Konkan Railway

Origin-Destination	Distance (Kms)			Travel Time (Hrs)		
	Before	After	Saving	Before	After	Saving
Mumbai-Mangalore	2041	914	1127	41	15	26
Ahmedabad-Mangalore	2653	1358	1295	58	32	26
Delhi-Mangalore	3033	2249	784	65	39	26
Mumbai-Cochin	1849	1336	513	36	24	12
Madgaon-Mumbai	629	444	175	20	10	10

Source: Konkan Railway Corporation Limited,1998, A Dream Come True, KRCL.
Note: Travel time saving is calculated for average speed of 100km per hour. For comparison of fares and time taken for origin-destination pairs by road vs rail see ***Table 4***.

3.2.2 Environmental controversy

Just as for a number of other large-scale infrastructure projects involving significant public investment – such as dams, highways, railways, and airports – the Konkan Railway has been the subject of controversies in which environmental and development concerns have been pitted against each other. When the Konkan Railway was proposed it ran into controversy in the State of Goa. The conflict was not so much about constructing the Konkan Railway through Goa, but about the alignment chosen by the KRCL. The demand was that the alignment be shifted to pass through the mining belt or the hinterland rather than coastal Goa. Concerns were raised regarding the damage it would cause to the mangrove swamps, the Khazan lands (low lying estuarine lands managed through a traditional technique of tidal flow management), the wetlands, the wildlife sanctuaries, and generally the ecosystem of the region. It was alleged that the alignment would be detrimental to the ecosystem and ecological balance of the region; it would fragment and significantly alter the socio-cultural life of the coastal communities; that Goa was just being used as a corridor to link Maharashtra, Karnataka and Kerala and that the Konkan Railway would not bring any socioeconomic benefit to Goa. The environmental protests ensured that the project went through multiple stages of expert assessment.(Alvares 2002; Panandiker and Ribeiro 1993; Rodrigues 1993; Shankar 1992). More recently, the Konkan Railway was identified as a "contested space of environment versus development" in a 2011 report on the conservation of the Western Ghats, submitted to the Ministry of Environment and Forests, Government of India (Gadgil et al., 2011). For the supporters of the project, however, the Konkan Railway was an engineering marvel that was built using the latest technology; a symbol of modernizing India and a matter of national pride. It was described in various superlatives such as the biggest railway construction project undertaken in independent India and through one of the world's toughest terrain. It was expected that the Railway would open up the whole area for people to move faster; it would usher an era of development of a hitherto backward region whose industrial and developmental potential has remained unrealized for the want of a transport network integrating it to the rest of the country.

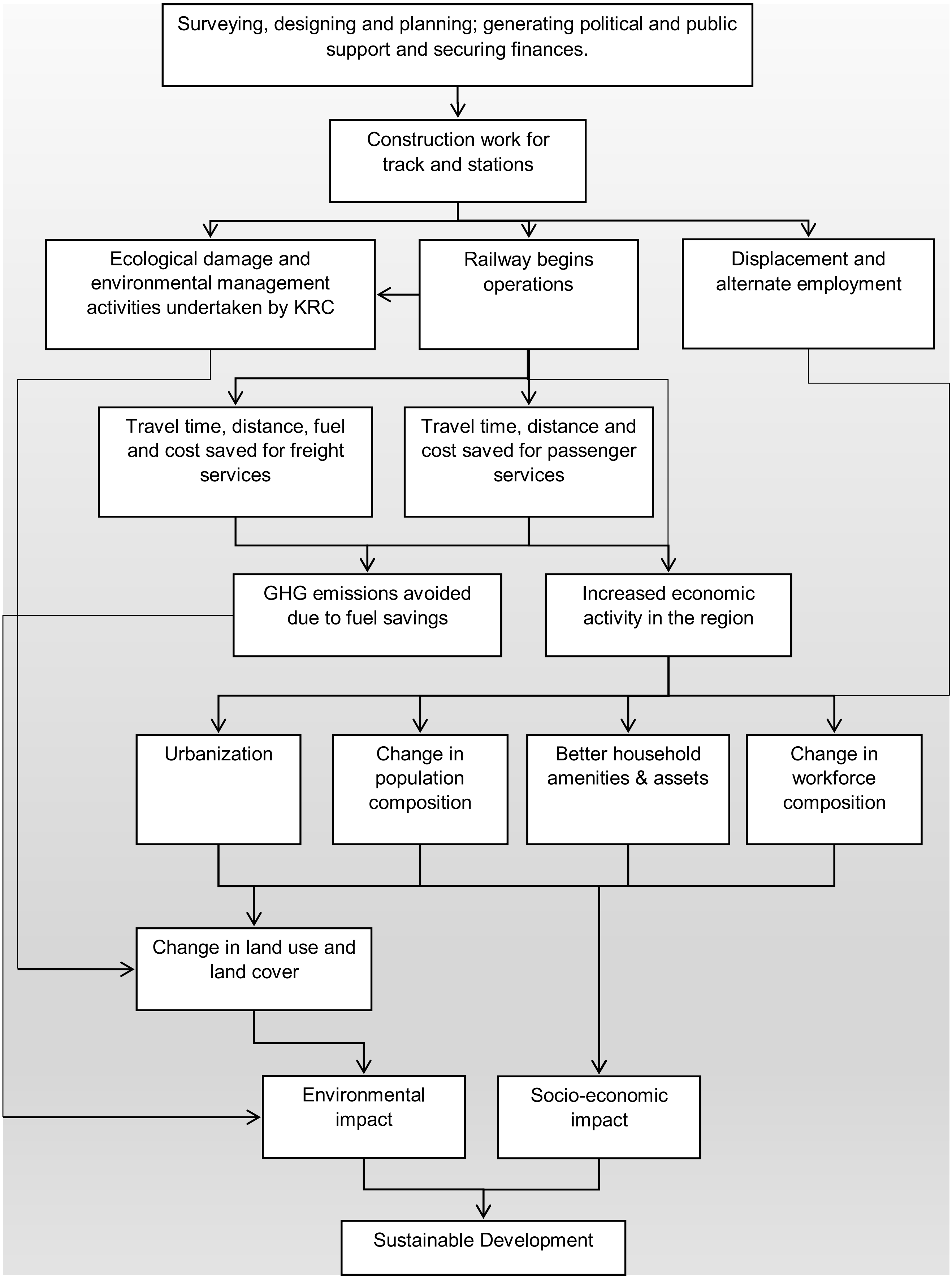
4. Theory of change and research hypotheses

4.1 Theory of Change

Transport infrastructure, has direct effects chiefly in terms of transport cost and time savings for passengers andfreight. It also has indirect and wider economic effects by further affecting household and firm economic behaviour, for example by increasing travel among the former and reduction in production costs for the latter (Rodrigue, Comtois and Slack 2016). Given suitable accompanying circumstances and endowments of an area, it can influence land use patterns and facilitate industrial and urban agglomerations. Railway infrastructure, in particular, is claimed to encourage access to markets, promote trade, alter livelihood opportunities, bring about changes in incomes, as well as rural-urban dynamics and promote overall economic growth. (See Figure 1). There can also be important distributional consequences of access to railways. Areas that get access to railway infrastructure may grow faster and show better socioeconomic outcomes. As labour and capital relocate to places with better transport infrastructure, neighbouring areas may experience a simultaneous reduction in growth. Moreover, by increasing the access of rural regions to cities, it may cause relocations of capital and labour over time. The impact of the railways on socioeconomic and environmental conditions may also show a decreasing – though not necessarily linear – trend the further away we move from the railway infrastructure. It is also plausible that, depending on the initial context, districts, towns or villages show different improvements in outcomes. Districts located closer to a major industrial centre might show better outcomes than those located further.

In the case of the Konkan Railway specifically, as the Konkan region is characterized by outmigration for employment and education, Konkan Railway was promoted as a project that would usher in an era of development of a hitherto backward region whose industrial and developmental potential has remained unrealized for the want of a railway network. It would do so by integrating it to the rest of the country and providing a means of transport for its mineral, forest and marine resource. It would give a stimulus to petrochemical, metallurgical and food processing industries in the region, enhance its tourism potential and create job opportunities.

Figure 1: Theory of Change for Konkan Railway



During the construction phase, a large infrastructure project can stimulate the local economy. There will also be social impacts such as displaced families and environmental impacts. Beyond a variety of local, regional and national level social and economic benefits, railway infrastructure can have a bearing on the environment during both its construction and operation phase. The construction of railways, involves tunnelling (blasting), cutting of natural slope and embankment, removal of vegetation cover and also demolition or restructuring of existing human settlements. These activities can be expected to alter the existing physical, hydrological and biological environment of the region. In general, it leads to immediate outcomes such as loss of vegetation cover, forest fragmentation, loss of water bodies and other forms of environmental degradation.

The environmental groups protesting against the Konkan Railway had argued that the tracks will cause damage to the ecosystem formed by River Mandovi and Zuari, mangrove swamps, the Khazan lands (low lying estuarine lands managed through the traditional technique of tidal flow management), the wetlands, and the Carambolim Lake (famous for its migratory birds) and would generally be detrimental to ecosystem and ecological balance of the region. Environmental deterioration is likely to be more severe in areas along the line than those away. However, in the long run, there may also be afforestation activities undertaken by the railway authorities to stabilize the track, and engineering solutions may be implemented to address fragmentation.

For transport infrastructure to induce the kind of wider socioeconomic effects which is the subject of this study, the transportation project is of course a necessary condition (by providing new or improved access), but is not a sufficient condition (Handy 2005). The induced effects to occur, requires the following favourable conditions generally and in the specific case of the Konkan Railway: (i) the presence of the Konkan Railway would encourage industrial investment in the region (ii) political and regulatory conditions as well as the overall macro-economic environment would support overall development iii) Railways would continue to remain the commercially preferred option for transport of heavy bulk commodities. Development of other infrastructure. For example, KRCL expected a number of ports to be developed in the region over the years, which would take advantage of the railway link.

4.2 Research questions

We seek to evaluate the socioeconomic and environmental impact of the Konkan Railway. Specifically, the evaluation questions this study seeks to answer and the hypotheses based on them are:

- What are the socioeconomic impacts of the Konkan Railway?
  H1: Access to the railway will boost economic activities in the catchment area which will, in turn, lead to a change in composition of the economic activities and the workforce, as the population moves from primary to secondary and tertiary sectors.
- What has been the effect of Konkan Railway on the land use pattern in the region?
  H2: The presence of the railway will have an impact on the environment.
- Have the stated project objectives of the Konkan Railway been achieved, including improvements in connectivity, a reduction in distance and travel time, and projected freight movement?

5. Context

5.1 The Konkan region

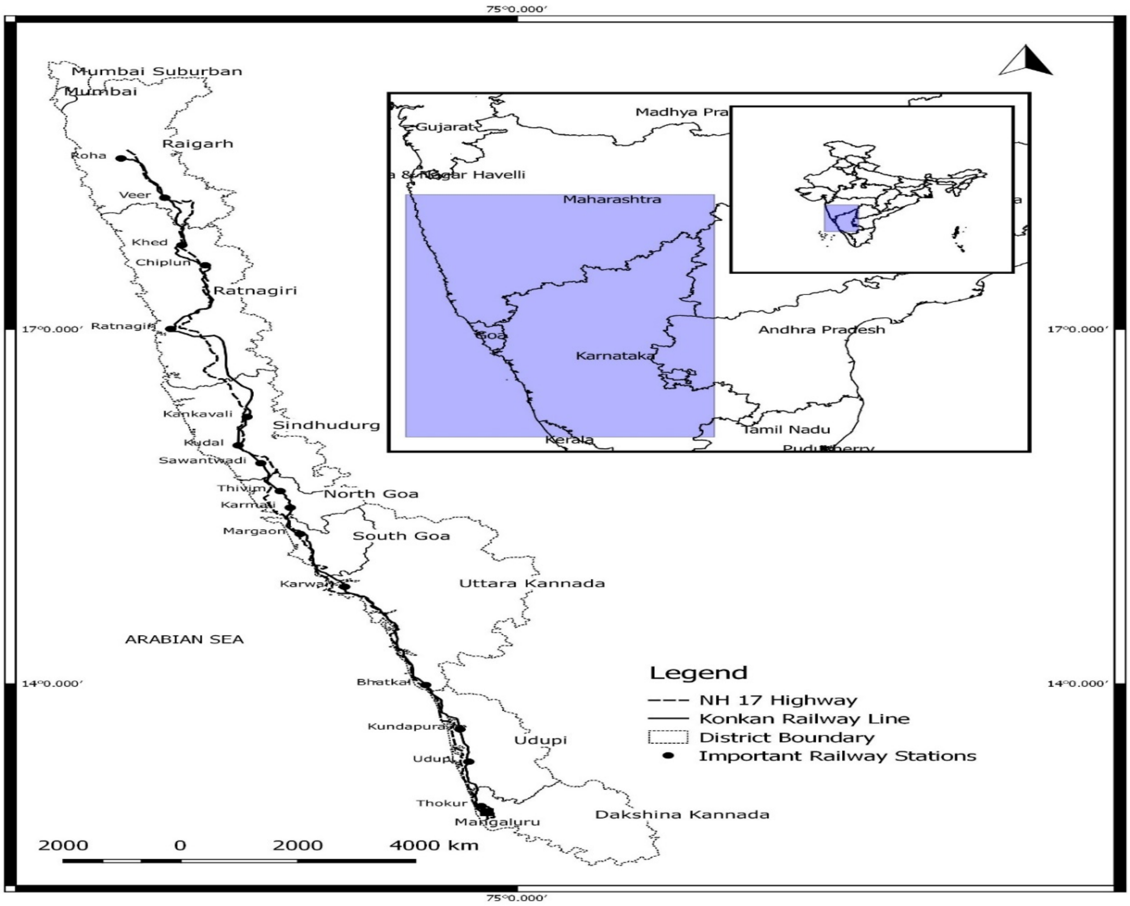
The Konkan Railway was built to connect the Konkan region to the rest of the country. The Konkan region is a narrow strip of the western coastline of India comprising the coastal districts of Maharashtra, Goa and Karnataka. It is bounded by the Arabian Sea on the west and by the Western Ghats – a chain of mountains that run parallel to the western coast for 1600 km – on the east. Specifically, the Konkan Railway traverses three districts in Maharashtra (Ratnagiri, Sindhudurg and Raigarh), two districts that make up the state of Goa (North Goa and South Goa) and three districts of Karnataka (Uttara Kannada, Dakshina Kannada and Udupi) (see Figure 2). As of 1991, Ratnagiri and Sindhudurg were considered to be underdeveloped in relation to Mumbai in terms of per capita income.(Tumbe 2012; Sita and Prabhu 1989) However, these districts still perform better than some of the other districts of Maharashtra and also most parts of India (Tumbe 2012). Goa, one of the smallest and more prosperous states of India is dependent on tourism, mining and remittances as sources of income. The Portuguese ruled Goa for close to 450 years and it became a part of India only in 1961. A high-powered committee on the redressal of regional imbalances set up by the Karnataka government, classified the sub-districts in Karnataka into four categories: relatively developed; backward; more backward and most backward in its 2001 report (Nanjundappa and Sinha 1982). All the sub-districts of Udupi and Dakshina Kannada were classified as relatively developed. Out of the five sub-districts of Uttara Kannada traversed by the Konkan Railway, three were classified as relatively developed (Karwar, Kumta and Honnavar), one as backward (Ankola), one as more backward (Bhatkal). Notably, there were no most backward sub-districts in coastal Karnataka.

A common feature that unites all these districts is the high level of male outmigration in search of better economic opportunities. The Konkan region has a very long history, going as far back as 19th century and even earlier, of migration of male members of the family in search of better economic opportunities and as a livelihood diversification strategy (Tumbe 2012, 2015; Thorat, Dhekale, Patil and Tilekar 2011; Sita and Prabhu 1989).Several studies over the years have found that, apart from being male dominated, the migration from this region is remittance-based, circular and largely directed towards Mumbai (Ibid). As the migration from the Konkan region has been male dominated, this region has had a historically high sex ratio. Tumbe notes that between 1881 and 2011, the female to male sex ratio of Ratnagiri district for example, never fell below 1100, indicating a persistently high male deficit due to outmigration.[2] Remittances form an integral part of the migrant households' livelihood strategy giving the Konkan region the epithet of being a 'money-order economy', as the household members frequently sent back home postal money orders from elsewhere to support families, to build or remodel homes, to purchase land, and to invest in small businesses and other avenues (Tumbe 2012). People who have migrated with their families, prefer to retire in their native places after spending their prime working years outside. It is referred to as circular migration as the migrants do not snap their native connection, visiting their homes at least once a

[2] In 1991, the sex ratio for Maharashtra, Goa and Karnataka was 934, 967 and 960 respectively. In 2011, the sex ratio for Maharashtra, Goa and Karnataka was 929, 973 and 973 respectively.

year for religious festivals, for worshipping the family deity, to supervise cultivation on their land during the sowing season or for family celebrations such as weddings(Tumbe 2012). Family is understood in a much broader sense than just the nuclear family. It refers to the joint network of kith and kin.Though there are certain variations in choice of destination for migrants, Mumbai with its opportunities in industries and services acts as the most significant pull centre for migrants from this region.

Figure 2: The Konkan Railway and the districts through which it passes



Source: The map is generated by processing multi-temporal and multi-spectral satellite data procured from USGS and NRSC

6. Evaluation design

A transport infrastructure project has elements of both a ‘complicated’ and ‘complex’ intervention. An infrastructure project is a ‘complicated intervention’ because multiple causal strands are needed to produce the impact (Rogers 2009). It is also a ‘complex’ intervention with the causality being recursive, with feedback loops making the cause-effect relationship mutual, multi-directional and multilateral (Rogers, 2009, 2008,See also Pawson, 2006).. Against this background, we propose a series of steps to be followed in an impact evaluation of large-infrastructure projects and implemented in the case of the Konkan Railway (Figure 3). As will be explained, these steps inform each other and sometimes overlap. The phased mixed-methods approach suggested by Broegaard et al. (2011) is a somewhat similar approach to the one employed here. Overall, we construct a theory-based evaluation using mixed-methods for assessing the impact of the Konkan Railway and to uncover the context and the causal mechanisms.

Figure 3: Steps in the proposed impact evaluation framework

Step 1. Development of a comprehensive theory of change of the intervention to derive indicators of the intermediate outcome and ultimate impact level
Step 2. Archival research to understand the project context
Step 3. Assessment of intermediate outcomes to substantiate (or refute) the theory of change
Step 4. Econometric data analysis to determine average impact estimates
Step 5. Collection of qualitative information (key informant interviews) to complement the quantitative data and for assessment of impacts not captured by econometric data analysis
Step 6. Exploration of heterogeneity to understand distributional consequences
Step 7 Discussion on external validity (Conclusion and Policy implications)

The various steps inform one another and is supposed to yield both triangulation (provision of different pieces of evidence for a more comprehensive understanding of the various facets of a complex object of study) and evidential variety (provision of different pieces of evidence to confirm specific propositions) (Claveau 2011).

6.1 Step 1: Develop Theory of Change

In a first step, we developed a comprehensive theory of change of the intervention outlined in Section 4. The theory of change reflects our evaluation questions and connects the intervention's inputs and activities to its outcomes and impacts in generic terms. It thereby helps in exposing the main assumptions behind the underlying causal relationships. This theory of change forms the basis for our solid theory-based evaluation and serves to derive indicators on the intermediate outcomes and ultimate impacts to be assessed.

6.2 Step 2: Archival research

We undertook archival research to understand the broad contours of the socio-economic and political context in which the project came to be implemented. We carried out a thematic analysis of the reportage on the Konkan Railway in India's leading English-language newspapers and magazines during its pre- and post-implementation phase (between 1990 and 2004). This was supplemented with a review of letters from citizens pertaining to various aspects of the Konkan Railway published in newspapers, the environment impact assessment reports, reports of various committees appointed to look into the controversy, court cases and material published by environmental organizations. This exercise also helped in understanding the expectations from the project, specific issues that were brought up by environmental and citizens' groups in connection with the construction and operation of the Konkan Railway project such as damage to environmental and cultural heritage. More generally, the documents yielded additional insight into the development experience and the nature of environmentalism around large-scale development projects in the region. Our findings from this exercise is summarized in Jaiswal (2018).

6.3 Step 3: Descriptive Analysis of Intermediate outcomes

As previously elaborated, the long-term impacts of the Konkan Railway would be derived from a long chain of intermediate outcomes to produce the intended impact on economic activity and land use changes. For this purpose, we carried out an assessment of the intermediate performance outcomes to substantiate (or refute) the theory of change and to explore the reasons for under/over-performance of the Konkan Railway. We explore if the Konkan Railway has achieved its stated projected objectives of improving connectivity and reduction in distance and travel time for passengers and freight and whether it generated the projected passenger and freight traffic. This was done using mostly qualitative and single-difference evaluation approaches. We reviewed the trends in passenger and freight movement. We also calculated the shortfall in the actual and projected passenger and freight movement. We analysed the origin and destination of freight movement to understand the nature of the users of the freight services, the economic activities occurring in the region relating to the Konkan Railway's freight movement and the impact of changes in regulations on freight services. The data for various indicators was collected from various departments of KRCL.

6.4 Step 4 Key informant Interviews

Given the geographical spread of the Konkan Railway, gathering qualitative data on the impact of the Konkan Railway is a challenging task. Therefore, we focused on capturing a broad impression of the impact of the Konkan Railway through key informant interviews. Key informants were identified based on the considerations such as local, historical and experiential knowledge of the Konkan Railway and grouped into four categories: i) the elected heads (Sarpanchs) of the village self-governing bodies also known as the Gram Panchayat. They were chosen because as elected representatives they were well situated to respond to questions on how the Konkan Railway has been experienced by the village and in many instances also possessed historical knowledge of the project ii) KRCL officials and engineers. iii) representatives from industry and trade iv) activists, environmentalists, citizens, who were the key players and journalists who reported on the Konkan Railway realignment controversy during the 1990's. **Table 1** below lists the number of key informants interviewed in each category and how they were identified. In all, 84 semi-structured key informant interviews were carried out. As Goa, was the focal point of the resistance against the Konkan Railway's chosen alignment, we additionally interviewed civil society and political figures in Goa. The semi-structured interview schedules were tailored to suit the category to which the interviewee belonged (See Appendix for Questionnaires).

Table 2: Key informant interview categories

Category	Description	No. of Interviewees	How was the informant identified?
Local self government bodies	Village Sarpanch, Deputy Sarpanch or Panchayat Members	60	2 village panchayats in each sub-districts through which the railway traverses were identified from the Census of India, 2011 and selected on the criteria that the villages falling in these panchayats were within 10 km from the Konkan Railway stations, with a mix of those in proximity to the highway, local stations (where only a few trains would halt) or major stations.
Civil society	Activists, environmentalists	7	Identified from the newspaper analysis of the Konkan Railway Controversy.
Industry/trade representatives	Actual Users of freight services and those identified in the projection study.	11	Current users identified from the freight movement data. Potential users Identified from the RITES Traffic projection study.
KRCL	Top Officials	7	Key KRCL officials in positions of responsibility.

The aim of the was to gather additional evidence to 'confirm', 'explain' the econometric data analysis and 'enrich' the overall analysis in line with Carvalho and White (1997). Additionally, the key informant interviews were also aimed at teasing out information on those aspects of the impact which the quantitative approach is unable to capture. These include distribution of costs and benefit and user attitudes and preferences for rail travel. Specifically, this exercise is aimed at understanding the various purposes for which people travel, local perception about the impact of the Konkan Railway, people's preference for road versus rail for long distance travel; changing preference for mode of transport for freight, main users of Konkan Railway's freight service, and challenges faced in increasing freight carried by Konkan Railway .Further, the key informant interviews were expected to enrich the analysis by enabling us to understand people's livelihood strategies including migration which further informs how the impact of Konkan Railway is mediated through the local context. The key informant interviews helped us get a broad picture of the emerging migration pattern for short-term work engagements. The key informant interviews also yielded several 'vignettes' on the effect of the Konkan Railway on individuals, households and villages (See Rogers, 2009).

6.5 Step 5 and 6: Quasi-Experimental socioeconomic impact evaluation

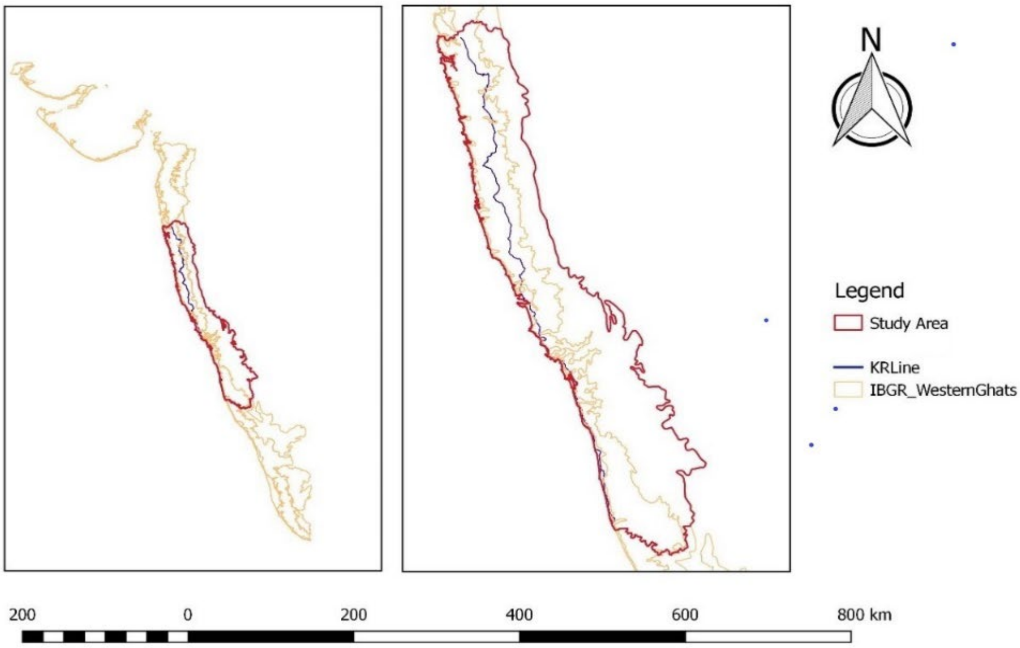
6.5.1 Identification strategy

For a large infrastructure project like the Konkan Railway, tackling the main methodological challenge of likely endogenous placement and selection bias deserves most attention. To start with, it can be argued that the actual KRCL track was largely determined by engineering criteria. Wang and Wu (2015) make a similar argument in the case of Qingzang railway in China. KRCL, resurveyed the alignment and reduced the length of the railway line from 837km suggested by the previous survey to its current 760km. This was done so that the chosen alignment could be as short and flat as possible in order to optimize load haulage and to be capable of carrying high speed trains at running at 160km/hr. The new alignment restricted the curvatures to a radius of 1250 metres or 1.4 degrees and adopted a uniform ruling gradient of 1 in 150 to optimize speed and haulage.[3] These parameters also meant that the length of the tunnels was increased as every time the track approached a hill it could not skirt around it. This increased the length and cost of the tunnels, but KRCL felt that the additional expense on tunnelling would be balanced by saving in length. For, certain areas within the limits of the set technical parameters, it tried to avoid heavily built up areas. This was done to avoid the complications in land acquisition and extra expenditure in terms of compensation paid out for the acquired land, and not because of their socioeconomic potential. In consequence, deviations from a straight line between the two termini of the track can be considered as largely uncorrelated with relevant socioeconomic baseline variables.

This exogeneity argument, however, is less applicable to the railway stations, which are the reference points to determine the indicator for treatment (intensity) in this study reflecting access to railways: the distance separating a locality from the nearest railway station. While the railway stations that happen to fall en-route the railway track, can be seen as an “exogenous event” or quasi-random shock along the lines of Chandra and Thompson (2000), the exact location of the railway stations remains a choice variable, which potentially creates an endogeneity bias: the initial conditions are likely to determine project placement, as well as influence the subsequent growth path and prospects of the villages and towns (Jalan and Ravallion 1998b). These potentially important initial locality conditions could be physical, geographical, social or economic conditions. We address these potential biases in two ways. Firstly, to account for initial area characteristics that might determine the future growth trajectory, we restrict our comparison units to the same bio-geographic zone as the treatment units. Bio-geographic regions are land units classified on the basis of their similarity of factors including altitude, climate, topography and vegetation. We use three bio-geographic provinces for the demarcation of the study area, these are (i) West Coast, (ii) Malabar plain region of Western Ghats and (iii) Mountainous region of Western Ghats. For the purpose of our study, we limit this study area to the north and to the south by excluding localities that lie beyond the two termini stations of the Konkan Railway. Therefore, we re-defined the north and south limits of the bio-geographic provinces to correspond to the start and the end stations of the Konkan Railway. The Konkan Railway termini stations are Roha in Raigarh district of Maharashtra and Thokur in Dakshina Kannada district of Karnataka. We furthermore exclude the two termini stations, Roha and Thokur, from the estimations considering them as endogenous, since the choice of these stations were a matter of design rather than fortuitousness. In 1998, the Konkan Railway had 54 railway stations including the termini stations.[4] Secondly, we use a modified difference-in-differences (DID) estimation framework as outlined below under Section 6.5.4.

[3] In the earlier survey conducted by Southern Railway, the ruling gradient for certain stretches was 1:100. The gross load that a WDM loco can haul over a gradient of 1 in 100 is 1500 tonnes, while on a 1 in 150 gradient it can haul 2400 tonnes. (Konkan Railway Corporation Limited 1999)
[4]More stations were added later. As of 2014-15, there are 58 stations on the Konkan Railway

Figure 4: Study area and Konkan Railway line



Note: The left panel shows the entire Bio-geographical Region of India (IBGR) relevant to the study and the study area as limited for the purpose of selecting the treatment and control localities using the termini stations of the Konkan Railway. The panel on right shows the zoomed in demarcated study area. The map is generated by processing multi-temporal and multi-spectral satellite data procured from USGS and NRSC

6.5.2 Data sources and outcomes of interest

In line with the research questions and the hypotheses laid out, we have divided the outcome variables of interest into three categories, each with its set of indicators: Workforce composition; Population Composition (Sex ratio, population, urban and rural population) and land use. Details of the outcome variables in each category along with their definition, source of data and differentiated by whether they are available for our rural and urban subsamples is presented in Appendix. The source of data for our outcome variables for population and workforce composition and land use is the Census of India for the years 1991, 2001 and 2011. Three points in time are covered by this study: (1) before the Konkan Railway project, 1991, (2) just after completion of Konkan Railway, 2001, and (3) around a decade after the completion of Konkan Railway, 2011. For our main analyses, we rely on the 1991 data as baseline data and the 2011 data as follow-up/ endline data. We also use the census data from 2001 to gauge the short-term impact of Konkan Railway. The level of observation is a locality, i.e. either a village or a town, of which approximately 7500 and 170 are in our sample, respectively.

In our quasi-experimental setup, it is particularly important to control for a number of locational factors. The control variables, namely distance from the highway, distance from the coast, elevation and latitude were generated using Geographic Information System (GIS) techniques using digitized village boundaries based on the 2011 (Goa and Maharashtra) and 2001 (Karnataka) village census maps and Digital Elevation Models (DEM). The method for extracting elevations at the centroids of the village shape boundaries using a spatial analyst tool is detailed in Appendix. The 1991, 2001 and 2011 census datasets were joined to the spatial attribute data in GIS based on the 2011 unique census identifier.

6.5.3 Treatment definition

The objective of the quantitative impact assessment is to assess the impact of the treatment *access to railways*. More specifically, we assume this treatment to affect the socioeconomic and environmental character of localities with different treatment intensities, depending on their distance to the railway facility. As a consequence, our treatment units will be localities, that is villages and towns, close to the railway station and comparison units will be localities further away but still in the same bio-geographic zone, depending on the distance to the nearest railway station. In quantifying the causal impact of the Konkan Railway, we not only adopt this definition of a continuous treatment that depends on distance, but also remodel it to different dichotomous treatment variables based on binary splits, which may be combined to form a categorical treatment interpretation using different distance bands. The distance is, in each case, measured as the Euclidean distance between the railway station and village/town computed using a GIS.

Binary Treatment, main specification

Binary treatment variables T_{d_c} use a cutoff distance *d_c* of localities from the nearest railway station at endline to assign them to a treatment or comparison status. T_{10km}, for example, implies that treatment units have a distance of 0 to 10 kms from the nearest railway station, whereas comparison units are more than 10 (and less than 100 kms) away from their nearest railway station. Alternative binary treatment and comparison unit definitions are used with cutoffs at 20 and 30 kms, where T_{xkm} splits the sample into treatment units with 0-x kms from railway station and comparison units with a distance of >xkms <100kms.

Binary Treatment, robustness checks

In order to check the robustness of our findings from the main specification, we run estimations for a slightly revised treatment definition T_{R_xkm} where comparison units are more than xkms but less than 50kms from the station. The reservoir of comparison units is thus restricted as compared to the 100km threshold used above. Here, we apply treatment cutoffs of 10 and 20km.

Categorical Treatment

Since the relationship between distance and treatment intensity is likely to be heterogenous across distances, we also apply a treatment definition based on multiple distance bands following Ghani, Goswami and Kerr (2016).

Continuous Treatment

Finally, we also apply a fully continuous treatment definition, where we use distance *d* directly to test whether polynomial functional forms based on distance are more appropriate.

6.5.4 Difference-in-Differences specifications

In our quasi-experimental setup, it is particularly important to control for a number of locational factors, in particular local highway infrastructure, but also elevation, for example. Even though the highway that runs close to Konkan Railway was built in the 1960’s and 1970’s, it may exert a time-varying effect on our outcomes during the time-period observed in our study. Since the distance from the highway, however, is time-invariant (as most of the other factors as well), it would drop out from a conventional DID analysis.

To be able to account for such factors and thus to reduce the risk of bias stemming from endogenous placement, we apply a modified DID framework in that the set of control variables at baseline $X_{i,0}$ is interacted[5] with the post-treatment time-period dummy P_t in the estimation (see the estimation equation [1] , [2] and [3] below).The set of time-constant baseline control variables $X_{i,0}$ in our case comprises elevation, latitude, distance from the highway and coast. Time-variant controls are not included since main candidates for it have to be considered as potential outcomes in our setup.[6]

Also, as opposed to a standard DID model, we introduce a locality fixed effect γ_i, which absorbs the coefficient with the simple treatment dummy (or dummies) T_i, as the same locality will not change status from treatment to control or vice versa between baseline and endline. In addition, we include a locality dummy $V_{i,t}$ in the model, indicating that the respective locality is a village (and not a town). This village dummy is not absorbed in the fixed effects as some localities change status from village to town or vice versa over time. This model is better suited than the standard DID when there are locality-level unobservables, that is omitted time-invariant variables, beyond what we already control for. The validity of the DID identification strategy relies on the assumption that the localities close to the railway station and other localities in our study area have common trends for outcomes of interest, which makes the change over time in the outcomes for the latter localities a good comparison set for the former set. As we have only one pre-treatment period, it is not possible to test the common trends assumption based on pre-treatment trends. Given the absence of two pre-treatment datasets as a means to test this assumption, we alternatively tabulated the baseline levels of the outcomes for our treatment definitions as similar levels at baseline might be suggestive of similar trends as well. We performed a standard *t*-test to compare mean differences between the treated and comparison groups for our outcome variables at baseline for T_{10km}. The results are presented in ***Table 5*** under Section 8. We find that the direction of the mean differences between the treatment and comparison is a bit mixed, for example, we find no significant difference between treatment and comparison group for percentage of main workers to total workers for the year 1991 for treatment definition T_{10km} . The mean differences are larger for population (higher for treated localities) and for forest area (lower for treated localities). In our study design we are using interactions between the post-treatment period and variables distance from the highway, latitude, elevation and distance from the coast and a modified DID setup with fixed effects to account for some imbalance at baseline. Together this is expected to control for differential trends to a considerable extent. Datta (2012) and Wang and Wu (2015) use a similar strategy for their work on the impact of improved highways and railways respectively.

[5] This approach is inspired by ANCOVA estimations (see McKenzie 2012, Hidrobo, Peterman, and Heise 2016 and Chen et al. 2017).

[6]We do not cluster standard errors, as in our view, the main points raised by (Bertrand, Duflo and Mullainathan 2004). (serial correlation in DID with many time periods and unit of analysis error) do not apply to our study and that (Abadie et.al 2017) clearly recommend us not to cluster: "The researcher should assess whether the sampling process is clustered or not, and whether the assignment mechanism is clustered. If the answer to both is no, one should not adjust the standard errors for clustering, irrespective of whether such an adjustment would change the standard errors."

Specification for binary treatment definition
The baseline model using the binary treatment definition then takes the following form:

$$Y_{i,t} = \alpha + \beta_1 P_t + \beta_2 P_t T_i + \boldsymbol{\beta_3}'\boldsymbol{X_{i,0}P_t} + \beta_4 V_{i,t} + \gamma_i + \varepsilon_{i,t} \text{........................[1]}$$

with Y as our outcome variable (see Appendix) and i as the locality at time t, representing either the baseline (1991) or endline (2011 and 2001 to see short-term impacts). The set of time-constant baseline control variables $X_{i,0}$ comprises of elevation, distance from the highway, distance from the coast and latitude. β_2 is our DID coefficient, which is our measure of the treatment effect.

Specification for categorical treatment definition
Equation [1] can be rewritten …

$$Y_{i,t} = \alpha + \beta_1 P_t + \sum_{b \in B} \beta_{2,b} P_t T_{i,b} + \boldsymbol{\beta_3}'\boldsymbol{X_{i,0}P_t} + \beta_4 V_{i,t} + \gamma_i + \varepsilon_{i,t} \text{........................[2]}$$

where the set B contains the four distance bands of localities between 0-5km, 5-10km, 10-20km and 20-30km. The excluded category are localities with a distance of more than 30 km. This equation is one way to non-parametrically assess the heterogeneity of impacts across different distances to the Konkan Railway stations.

Specification for continuous treatment definition
Alternatively, we use distance directly as treatment variable. Since we have distance from the nearest railway station only at endline, i.e. $d_{i,1}$ a flexible specification of the above equation looks as follows:

$$Y_{i,t} = \alpha + \beta_1 P_t + \beta_2 P_t d_{i,1} + \beta_3 P_t d_{i,1}^2 + \boldsymbol{\beta_4}'\boldsymbol{X_{i,0}P_t} + \beta_5 V_{i,t} + \gamma_i + \varepsilon_{i,t} \text{....[3]}$$

Additional heterogeneity analysis: station agglomeration as treated
The most important subgroup for which impacts may be assessed are the agglomerations which are directly served by the Konkan Railway stations. Apart from the two termini stations, Roha and Thokur, Konkan Railway had 52 station when it began full operations in 1998 (the number has gone up to 59 in recent years). These stations serve a total of 155 localities that form agglomerations around the stations. To give an example, the station named Honavar is situated in the village named Karki. The railway avoided going through the town Honavar as it would require constructing a much longer bridge across the river Sharavati. This also concurs with our argument earlier that that the actual KRCL track was largely determined by engineering criteria. Since the town of Honavar, however, is directly served by the station located at Karki, we consider the agglomeration comprising of the town Honavar, as well as further villages falling under the Karki Gram Panchayat, as treated by the railway station.

Additional Heterogeneity analysis: by distance to highway
In the above DID specifications, we controlled for the distance from the highway by interacting it as a continuous variable with time-period dummy. In a separate heterogeneity analysis, we adapt equation [1] in that we split the distance from the highway into three different bands H^b and interact these distance bands with the treatment T_i and time-period dummy P_t. We run three different estimations, where we consider localities in different distance bands b from the highway: 0 to 10, 10 to 20, 20-

30 km. In each of these estimations we consider as treated localities within 0-10 km from the railway station (T_{10km}).

The model then takes the following form:

$$Y_{i,t} = \alpha + \beta_1 P_t + \beta_2 P_t T_{10km} \mathrm{H}_{i,0}^{b} + \boldsymbol{\beta_3}' \boldsymbol{X_{i,0} P_t} + \beta_4 V_{i,t} + \gamma_i + \varepsilon_{i,t} \qquad [4]$$

β_2 is our DID coefficient, which is our measure of the treatment effect when we additionally interact the treatment and time-period dummies with a dummy that indicates whether or not the locality is located in the highway distance band at baseline. The set of control variables at baseline $X_{i,0}$ interacted with the post-treatment time-period dummy P_t in this estimation are distance from the coast, latitude and elevation. We compare the results of the three estimations to the base case of binary treatment definition of T_{10km},. These specifications allow us to determine heterogenous effects of railway access depending on differences in the simultaneous access to highways.

6.5.5 Statistical power

As elaborated previously, our study relies on census data for its main impact indicators. Against this background, it is debatable how far inferential statistics and sampling theory are applicable to this case. One could well argue that we already have data for the whole relevant population (both geographically and temporally) at hand, so that there is no need to generalize further. Still, we will apply standard significance tests throughout our analysis. The total population of villages and towns is approximately 7500 and 170, respectively. The analysis of outcomes that are only assessed for urban localities may thus well be underpowered. It has to be additionally noted that the analysis of different distance bands along the categorical treatment definition is obviously lower-powered than the analysis using only a binary treatment definition.

6.6 Step 5 and 6: Quasi-experimental Land use change impact evaluation

The census data on land use captures changes in land use within the locality boundaries. However, in the case of linear infrastructure such as the railway, it is important to consider land use change along the infrastructure, as the establishment and maintenance of railway lines cause direct loss of vegetation cover on either side of the line. Environmental deterioration is likely to be more severe in areas along the line than those away. We try to capture the land use change along the railway line using satellite data.

6.6.1 Data sources and outcomes of interest

The land use/land cover (LULC) have been extracted from the post hybrid classification analysis of multi-temporal multi-spectral satellite data. This dataset comprised of a mix of Landsat and LISS (Linear Integrated Self Scanning Sensor) satellite datasets for the years 1991, 2003 and 2014. Landsat TM data was used for the base year 1991 while LISS III was used for the years 2003 and 2014. For a detailed description of the methodology used for extracting the classified data from Landsat TM (Thematic Mapper) and LISS III, refer to the detailed LULC report in the Appendix.

Hybrid classification combines the unsupervised and supervised classification methods and enhances classification accuracy. Sader, Ahl and Liou (1995) have done a comparative study of the accuracy of various classification approaches and have found that the classification accuracy in hybrid method supersedes the unsupervised and supervised methods by using the case study of Acadian wetlands. Similarly, Ozesmi and Bauer (2002) have argued that rule based approaches like hybrid classification deliver better classification results in complex ecosystems.

Table 3: The LULC types as per Anderson's level -1 classification

LULC classes used in report	Corresponding Anderson's Level -I categories	Included LULCs in Anderson's Level I
Open Spaces	Urban Built – Up Land + Barren Land	Residential, Commercial, Industrial, Transportation, Mixed Urban, Dry Salt Flats, Beaches, bare exposed rock, strip mines, quarries, gravel pits, mixed barren land.
Water Bodies	Water	Streams and Canals, Lakes, Reservoirs, Bays and Estuaries.
Forest Cover	Forest Land	Deciduous Forest Land, Evergreen Forest Land, Mixed Forest Land.
Agricultural Land (Cropped and Uncropped)	Agricultural Land	Cropland and pasture, orchards, groves, vineyards, nurseries, ornamental horticultural areas, confined feeding operations, other agricultural land.

The LULC classes extracted are open space, forest cover, agricultural land and water body. Level 1 Anderson's classification standardized by the United States Geological Survey (USGS) forms a guiding schema for all LULC classification typologies. There is no single ideal type of a LULC classification typology as per Anderson et al. (1976) because of geographical variations. However, in the spirit of conceptualisation of LULC, where land use refers to "man's activities on land that are directly related to land" (Clawson and Stewart 1965: 402) and Land Cover referring to "the vegetational and artificial constructs covering a land surface" (Burley 1961), any observed LULC fits in to a standardized Anderson's classification criteria. The LULC types used in the report correspond to the categories outlined in Table 3 as per Anderson's level -1 classification. For a detailed description of the methodology used for extracting the supervised data from Landsat and LISS III, refer to the Appendix.

6.6.2 Treatment definition for land use change using satellite data

In this setup, the treatment region is on 2 km on either side of the main Konkan Railway line. A virtual line was drawn in GIS 10 km to the east of the main line and parallel to it. The area at 2 km on either side of the virtual line forms the control region. Therefore, from the treatment and control region we obtain 4km by 4 km boxes from the entire length of the railway track and from the virtual line (See ***Figure 5***). The outcome variable is the land use / land cover area expressed as percentage of the total area in the box. The treatment and the control distance variable is binary.

The 4 X 4 Km^2 squares in the treatment and control regions are 150 each, making the total number of samples 300. The total number of observations include observations in the pre and post-treatment periods i.e. 1991 and 2014. Hence the total number of observations are 600. The multi-temporal dataset covers an area of 59,444 Km^2. Figure

5 displays the details of the study area in the LULC report. In ***Figure 5***, panel Fig 5 (a) shows the area of analysis covered and Fig 5(b) shows the quasi-experimental design for the DID.

Figure 5: Study Area for satellite data classification analysis and schematic illustration of selection of control and treatment grids for the DID environmental impact assessment.

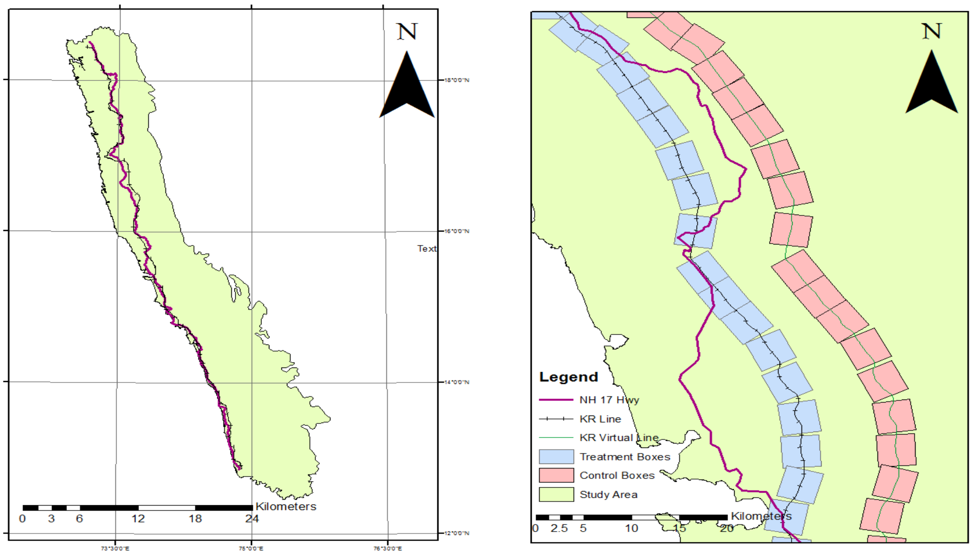


Fig 5 a) Complete Study Area

Fig 5 b) Treatment and Control Regions

Source: The map is generated by processing multi-temporal and multi-spectral satellite data procured from USGS and NRSC

6.6.3 DID specification

For the LULC analysis using the satellite images, we use a standard DID setup.

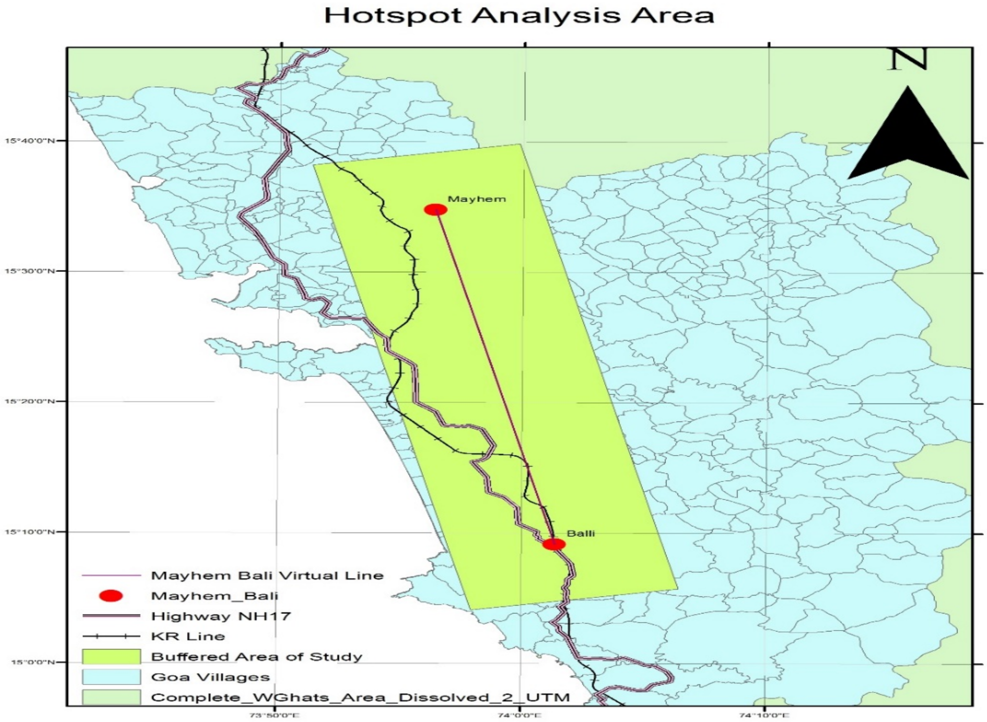
$$Y_{i,t} = \alpha + \beta_1 P_t + \beta_2 T_i + \beta_3 P_t T_i + \varepsilon_{i,t}$$

where Y as our land use change outcome variable and i as the 4 X 4 Km^2 squares at time t, representing either the baseline or endline and P_t is the post-treatment time-period dummy, β_3 is the DID coefficient and $\varepsilon_{i,t}$ the error term.

6.6.4 Heterogeneity analysis: Hotspot analysis

The 55km stretch between Mayem and Bali in Goa was used for hotspot analysis. The hotspot region was identified from the formative work and qualitative review of the controversy around the Konkan Railway alignment. The environmentalists in Goa had raised significant concerns regarding the adverse environmental impact the Konkan Railway alignment on this stretch. A virtual line was drawn between Mayem and Bali and an area of approximately 8 km on either side of the virtual line was buffered. The LULC values from the classified output within this region were extracted and the trend in LULC change over time periods 1991, 2003 and 2014 was observed. The GIS setup and the area of hotspot analysis can be seen in Figure 6.

Figure 6: Area of hotspot analysis



Source: The map is generated by processing multi-temporal and multi-spectral satellite data procured from USGS and NRSC

7. Main findings from analysis of intermediate outcomes and key informant interviews

The extent to which the theory of change earlier materializes in inducing the expected socioeconomic effects depends on a number of assumptions outlined earlier. We therefore assessed the intermediate performance outcomes to substantiate (or refute) the theory of change and to explore the reasons for under/over-performance of the Konkan Railway. We summarize the important insights that were generated from freight performance, passenger service performance and key informant interviews.

7.1 Freight performance

Between the year 2003-04 and 2016-17, the total freight traffic on the Konkan Railway in million tonnes has shown a cumulative average growth rate (CAGR) of 9 per cent.[7] Originating freight traffic, however has shown a negative CAGR of -4 per cent. Moreover, the freight traffic has not met the projections of the traffic projection study carried out by RITES. The shortfall between the projections by RITES and actual is 75 percent and 51

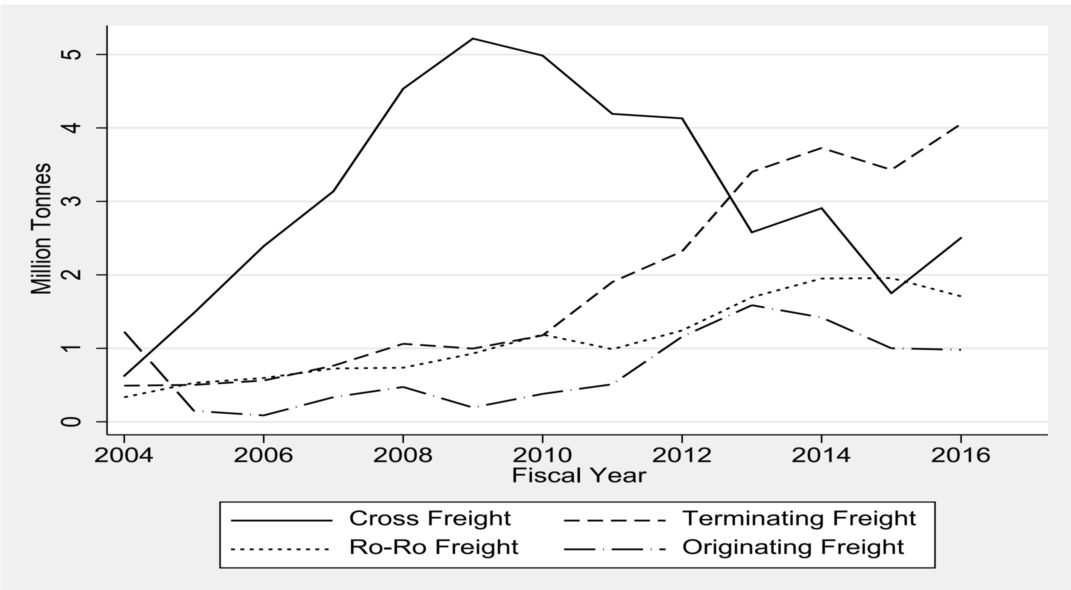
[7] The freight moved via the Konkan Railway can be divided into four categories: a) Originating:Freight originating on Konkan Railway stations and headed for different zones of the Indian Railway; b) Roll on-Roll Off (Ro-Ro) service, in which, goods trucks are carried piggy back on railway flat wagons c) Terminating traffic originates in one of the zones of the Indian Railway and terminates on stations on the Konkan Railway; d) Cross traffic is traffic through the Konkan Railway route originating from and destined to various zones of the Indian Railways.

per cent for the year 2005-06 and 2010-11 respectively. Despite offering significant reductions in distance and travel time, the projected freight movement on the Konkan Railway did not materialize because of several factors. To summarize: few industrial units planned for this region got relocated to other region, one was shut down and a few others which were expected to use Konkan Railway's freight services did not actually end up using it; the changing macro-economic conditions as well as the political, legal and regulatory scenario related to mining and environment affected the operations of some of the industrial units identified by the freight traffic projection survey; the changing business strategy for certain industries and the competition offered by other modes of transport has also affected the freight traffic performance of the Konkan Railway; The KRCL had also expected that a number of ports will be developed in this region to take advantage of the Konkan Railway. The progress on this front has been slow. Therefore, the overall freight scenario remained bleak and contrary to expectations. Since the demand for transport is a derived demand, that is, demand for transport occurs as a result of demand from other sectors, these regulatory uncertainties and resulting fall in the output of many industrial units affected the demand for freight services of Konkan Railway.

Almost all the members of the 60 Gram Panchayat we interviewed responded that the Konkan Railway had not brought about any industrial development. KRCL officials too generally responded that the Konkan Railway has not been successful in bringing about industrial development. Some of the common reasons they forwarded for this outcome were: failure of the state governments and the overall lack of political will in providing a proper climate for industrial investment; failure of the investors to take advantage of the railway line; the people in the region being environmentally conscious and generally being opposed to polluting industries; and slow progress on development of ports in the region.

Importantly, the findings of the freight performance cautioned us that the underperformance in terms of intermediate outcomes should make us more conservative in our expectations regarding the potential for socioeconomic and environmental impacts of the new Konkan Railway line

Figure 7: Freight Traffic on the Konkan Railway



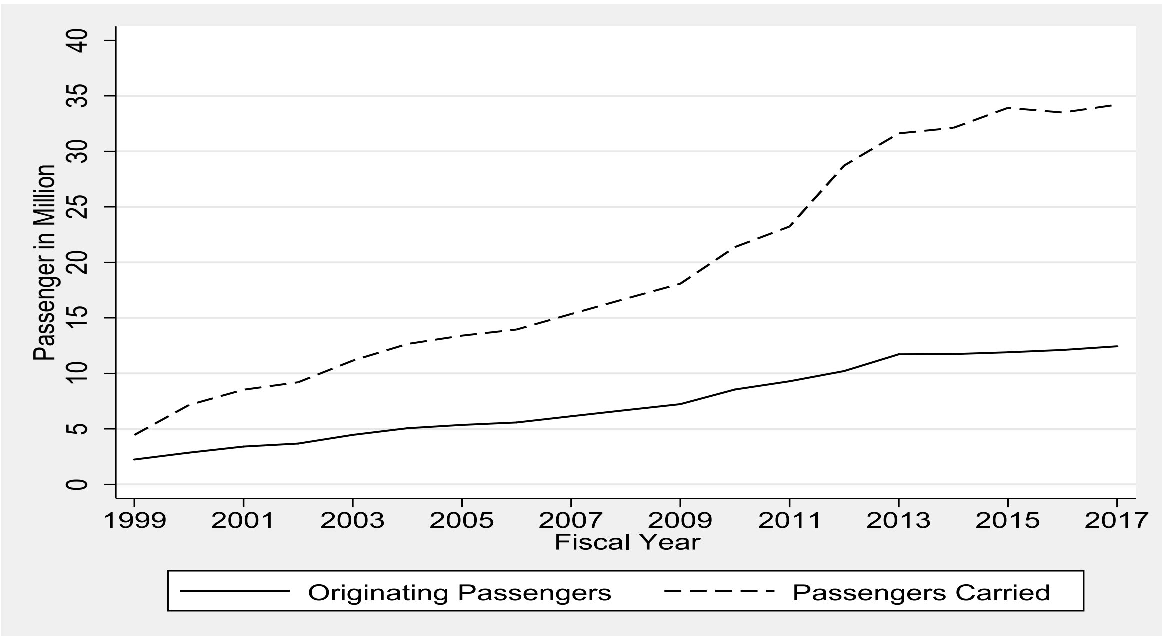
Source: Based on data provided by the KRCL.

7.2 Growth of passenger traffic

In contrast to the freight performance, the Konkan Railway has performed well when it comes to the demand for passenger service. The fact that the Konkan Railway has received patronage from the passengers is borne out by data and also by key informant interviews. Passengers carried by the Konkan Railway can be divided into originating passengers, passengers terminating their journey on the Konkan Railway stations and cross passengers who travel through the Konkan Railway route. Between 1998-99 and 2016-17, the passengers carried on the Konkan Railway route has seen a 6.7 times increase and the originating passengers have shown a 4.6-fold increase. Between 1998-99 and 2016-17, the CAGR of passengers carried on the Konkan Railway was 11 percent. For, originating passengers carried, the CAGR in the same period was 9 percent. Between, 1998-99 and 2016-17, originating passengers as a percentage of passengers carried has averaged around 39 percent.

The number of trains run on the route has also increased substantially. While, an average of 30 trains, including 23 passenger and 7 freight trains, were run on the Konkan Railway route in 2004-05, the numbers have gone up to 62 including 46 passengers and 16 freight trains in 2014-15. In order to meet the increasing demand of passengers, the Konkan Railway has routinely increased the frequency of trains and added new halts for some popular trains. It has also added more coaches to existing trains and run special trains every year to meet increased demand during religious festivals. The Konkan Railway, being a single-track line, in order to increase its line capacity, has also gradually added new halt and crossing stations and built new loop lines at a number of stations. But as of 2014-15, it is becoming increasingly difficult to introduce more trains on the network. In the near future, the Konkan Railway plans to build 21 new stations and 18 new loop lines to facilitate crossing of trains and increase line capacity (Rao 2016; Times News Network 2016)

Figure 8: Passenger Traffic on the Konkan Railway



Source: Based on data provided by the KRCL

7.3 Key informant interview analysis

Given the vast geographical spread of the area serviced by Konkan Railway, gathering qualitative data on the impact of the Konkan Railway is a challenging task. Therefore, in order to capture a broad impression of the distributional impact of the railway, the preference for long distance mode of transport and geographic labor mobility, heads of rural local self-government bodies were identified as key informants. They were interviewed to understand the socioeconomic profile of the village as regards to the primary source of employment for the residents; the long distance travel behaviour of the residents; preference for road vs railway transport; the impact of Konkan Railway on tourism, industrial development, migration, employment and education opportunities, the local environment; benefits and negative effects.

Upon analysis, the key informant interviews yielded several interesting themes and accompanying vignettes which provided an insight into the effect of the Konkan Railway on travel preferences, changing work profile and migration pattern in the region. It emerged that cost savings on account of subsidized train fare and constant fares as opposed to seasonally fluctuating bus fares has made it the preferred mode of transport for the region over highway. In order to get a sense of cost of transport in the region, ***Table 4*** compares train fare and bus fare using state transport buses for popular origin-destination pairs in the region which can be reached by the Konkan Railway as well as the highway. As can be seen from the table that for both the general category of tickets as well as Sleeper, the Konkan Railway provides significant saving in terms of cost and time and over state transport buses for similar origin-destination combinations. The cost of transport by private buses generally tend to be more than state transport buses.

This is not surprising because train fares in India are much lower as compared to private and state run buses, because the Indian Railways, operated by the Ministry of Railways, Government of India, has a policy of cross-subsidizing passenger fares using revenue generated from freight. The Indian Railways as a mandate to carry out certain transport activities which are essentially uneconomic in nature in the larger interest of the economically disadvantaged sections of the society. Losses incurred on this account fall under what is called the “social service obligation” of the Indian Railways. These losses are mostly due to low ordinary second class fare, suburban and non-suburban season fare, and a variety of concessions granted on passenger ticket (Railway Board 2016).[8]Within the passenger component it charges fares well below the costs across all classes (possible exception being Air-conditioned 2nd and 3rd class) for suburban and certain non-suburban classes. The extent of subsidy on passenger fares can be gathered from the fact that in the year 2015-16, low second class ordinary travel in both suburban and non-suburban constituted 78.8% of total traffic but constituted only 16.6% of total passenger earnings (Ibid). Moreover, unlike privately run buses there are no seasonal fluctuations in fares of regular trains. Due to the heavy subsidies provided by the State, combined with the low spending power of an average person in India, it is difficult for road transport to compete with rail in terms of cost for similar origin-destination pairs. Public policy, therefore, plays a significant role in shaping people’s choice for rail as the preferred mode of transport.

[8] Concessions are granted to various categories of passengers such as senior citizens, war widows, students, national sports awardees, persons suffering from serious illnesses such as cancer and tuberculosis

Table 4: Train and Bus fares and time taken for origin-destination combinations

		Train Fare (Rs)[1]	Time Taken (Hrs:Mins)		Time Taken (Hrs: Mins)	Bus Fare (Rs)[2]	Time Taken
	MUMBAI						
		General[4]		Sleeper[5]		MSRTC/ Kadamba /KSRTC	
Maharashtra	Chiplun	65	05:22	180	03:33	360	07:50
	Sangameshwar	75	05:32	210	04:20	480	08:15
	Ratnagiri	85	06:50	230	5:00	500	09:55
	Rajapur	95	08:48	265	06:11	605	11:00
	Kankavali	105	09:38	305	06:55	860	11:45
Goa	Madgaon	215	10:15	365	10:05	945	13:30
GOA							
Karnataka	Karwar	40	01:57	170	00:55	104	03:00
	Kumta	50	02:50	170	01:47	165	03:40
	Bhatkal	65	04:00	205	02:49	227	05:50
	Udupi	85	05:40	250	04:03	324	08:15
	Mangalore	95	07:23	290	05:55	385	09:30

Note:
1. The train fare is taken from the IRCTC (Indian railway catering and tourism corporation) website, an online portal for booking train tickets. Link - https://www.irctc.co.in/nget/train-search
2. The bus fare for public transport has been taken from state transport corporation websites of MSRTC (Maharashtra State Road Transport Corporation) for Maharashtra, KADAMBA for Goa and KSRTC (Karnataka State Road Transport Corporation) for Karnataka. Link - https://msrtc.mahaonline.gov.in/, http://goakadamba.com/, http://www.ksrtc.in/oprs-web/guest/home.do?h=1
3. To maintain consistency, fares are calculated till Panvel- a suburban station in Mumbai
4. The general ticket price for destinations in Maharashtra to Mumbai has been calculated from Diva-Sawantwadi Passenger train, for Goa- Mumbai from Mandovi Express and for destinations in Karnataka to Goa from Karwar-Madgaon DEMU
5. The ticket prices for Sleeper has been calculated from Konkan Kanya Express for Goa-Mumbai and from Matsyagandha for Goa-Karnataka.
6. All fares are as of 15th Nov, 2018.

Moreover, over and above the monetary factor, for the travellers the railways provide a tangibly different experience in terms of comfort, on board-facilities and safety which buses or an expanded highway network may not be able to match. However, though the railway and highway act more in complementary ways, the highway competes with the railway when the cost of first mile and last mile transport from the railway station is higher than the train fares.

In the next section we integrate the findings of the key informant interviews pertaining to migration and commute to work with the results of the econometric data analysis. In line with Carvalho and White (1997) the interview findings would be referred to in order to confirm, refute or explain in more details the results from the econometric data analysis.

8. Descriptive statistics

Table 5 presents descriptive statistics for the various outcomes studied in the subsequent impact analysis. We present means for the years 1999, 2001, and 2011, each for the entire sample as well as differentiated by treatment or comparison group as per our binary treatment definition T_{10km}.

For T_{10km}, we find that the sex ratio is higher for the treated localities as compared to the comparison one but falls for both between 1991 and 2011. Rural population, on the other hand, is higher in the treated localities as compared to the control, and rises for both between 1991 and 2001, then falls between 2001 and 2011. Additionally, the crude workforce participation rate rises slightly for both the treatment and control localities between 1991 and 2001 and then falls again between 2001-2011.The percentage of main workers to total workers falls sharply for treatment and control localities between 1991 and 2011.

Table 5: Descriptive Statistics for the study area and for T_{10km}

Variables*		Mean 1991	2001	2011
Population in individuals	Total	1114	1220	1251
	Treatment	1751.00	1956.00	2046.00
	Control	904.40	977.70	990.10
	Difference	846.19***	978.47***	1055.68***
Urban Population in individuals	Total	16695	18013	15154
	Treatment	20892	19680	15421
	Control	13840	16487	14833
	Difference	7052.00	3193.00	587.5
Rural Population in individuals	Total	943.8	996.5	960.1
	Treatment	1403.00	1482.00	1397.00
	Control	791.60	838.50	820.30
	Difference	610.93***	643.46***	576.37***
Female to Male Sex Ratio	Total	1116	1090	1071
	Treatment	1148.00	1115.00	1091.00
	Control	1107.00	1083.00	1065.00
	Difference	41.12***	32.12***	26.07***
CWPR in % (Crude workforce participation rate)	Total	47.77	49.68	48.4
	Treatment	44.33	46.25	44.50
	Control	48.88	50.78	49.64
	Difference	-4.55***	-4.53***	-5.14***
Main workers in %	Total	87.26	74.47	78.48
	Treatment	86.88	46.25	44.50
	Control	87.32	50.78	49.64
	Difference	-0.44	-4.53***	-5.14***
Male Main workers in %	Total	54.25	48.33	52.36
	Treatment	52.83	46.71	50.99
	Control	54.61	48.80	52.80
	Difference	1.79***	2.09***	1.81***
Cultivators in %	Total	57.95	49.42	42.42
	Treatment	55.94	44.31	34.62

Variables*		Mean		
		1991	2001	2011
	Control	58.86	51.29	45.17
	Difference	-2.92***	-6.98***	-10.55***
Agricultural labour in %	Total	19.44	14.73	20.94
	Treatment	14.05	10.54	15.63
	Control	21.02	15.96	22.54
	Difference	-6.97***	-5.42***	-6.90***
Household Industry Workers in %	Total	1.18	2.52	1.8
	Treatment	1.66	3.39	2.53
	Control	1.04	2.25	1.56
	Difference	0.62***	1.14***	0.96***
Other workers in %	Total	21.43	33.32	34.84
	Treatment	28.35	41.76	47.21
	Control	19.08	30.51	30.73
	Difference	9.27***	11.25***	16.49***
Forest Land in hectares	Total	217.9	223.9	223.6
	Treatment	83.91	80.56	83.65
	Control	260.00	269.20	266.70
	Difference	-176.10***	-188.60***	-183.05***
Cultivated Area in hectares	Total	210.7	263.8	187.2
	Treatment	217.60	243.40	180.20
	Control	206.60	270.60	187.30
	Difference	10.97	-27.22***	-7.16
Area not under agricultural uses in hectares	Total	118.7	103.3	93.02
	Treatment	120.50	95.09	98.02
	Control	118.10	106.30	91.78
	Difference	2.38	-11.26**	6.24
Culturable Wasteland in hectares	Total	130.8	109.2	55.67
	Treatment	123.80	113.70	71.48
	Control	132.30	106.40	50.27
	Difference	-8.52	7.27	21.21***
Note: See Appendix for definition of outcome variables and data sources				

For T_{10km}, for both the treatment and control localities percentage of main cultivators to total main workers falls between 1991 and 2001 and then again between 2001 and 2011. For both the treated and comparison localities, percentage of agricultural labour to total main workers falls between 1991 and 2001 and then rises between 2001 and 2011. Across the two decades, the percentage of main cultivators and agricultural labour is lower in the treated localities as compared to comparison ones. For T_{10km}, percentage of household industry workers to total main workers rises between 1991 and 2001 and then falls between 2001 and 2011 for both treated and comparison localities. The percentage of other workers to the total workers rises for treated and comparison localities between 1991 and 2001 and 2001 and 2011.

9. Results and Discussion from DID analysis

9.1 Main analysis

Table 6 and Table 7 summarize the DID results for different binary treatment definitions , robustness checks and categorical treatment. Figure 9 plots the results from the categorical treatment specification which helps us to understand the heterogeneity of impacts across different distances to the Konkan Railway stations. Tables for the complete estimation results of each treatment definition, is presented in the Appendix.

9.1.1 Population and workforce composition

A common feature of the districts through which the Konkan Railway passes is the high level of male outmigration in search of better economic opportunities. As the migration from the Konkan region has been male dominated, this region has had a historically high female to male sex ratio. Tumbe (2012) notes that between 1881 and 2011, the sex ratio of Ratnagiri district, never fell below 1100, indicating a persistently high male deficit due to outmigration.[9] Similarly, he notes that the sex ratio for Udupi district never fell below 1090 across the twentieth century. Dakshina Kannada too had a high sex ratio throughout the twentieth century). Prior to the annexation by India in 1961, the sex ratio of Goa averaged around 1098 between 1901 and 1961. However, from 1971 onwards the sex ratio declined and ceased to be a reliable indicator for outmigration, as the boom in the tourism, construction and mining sector in Goa led to considerable in-migration (Ibid).

With the advent of the Konkan Railway, the impact on female to male sex ratio on the treated localities is interesting. Overall the study area had a high sex ratio at 1116 in 1991 which fell to 1071 in 2011. For T_{10km}, the sex ratio, rises by 18 females in the treated localities as compared to the comparison ones, when the mean for the comparison locality is 1107 (the results being significant at the 1 percent level). The result is not significant for T_{20km} and T_{30km}. On checking these findings for robustness against a treatment definition where the treated localities are defined as those located 0-10 kms from a railway station, and comparison localities as located 11-50 kms away (T_{R_10Km}), the results show that the sex ratio increases by 22 females. As already indicated by the stark differences across the three binary treatment cutoffs T_{10km} , T_{20km} and T_{30km}, the graph for the outcome sex ratio for categorical treatment in **Figure 9** shows a rather noisy relationship to the treatment intensity measured by the distance to the nearest railway station. In the distance bands between 10 and 20 km, coefficients are even fairly strongly negative.[10] This also suggests a non-linear relationship between distance and impact, which will be analysed in more detail in Section 9.1.3 below.

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[9] In 1991, the sex ratio for Maharashtra, Goa and Karnataka was 934, 967 and 960 respectively. In 2011, the sex ratio for Maharashtra, Goa and Karnataka was 929, 973 and 973 respectively.

[10] The stronger/ more significant effect for the binary treatment as compared to the categorical treatment here is, first, due to the fact that the comparison group in the binary case also includes the distance bands 10-30 km, which show much lower values. Hence, the comparison group >10km has a lower value than the comparison group >30km, which makes the impact estimate for <10km vs >10km to be higher than for <10km versus >30km. Second, the analysis with multiple distance bands is also lower-powered (see section 6.5.5), especially when you look at the 20-30km band (with relatively fewer observations) as compared to the 0-30km binary definition, for example.] Similar explanation also applies to the results of other outcome variables

We find that the main workers (defined in the census as those who work for more than six months in a year) as a percentage of total workers, has decreased for treated localities as compared to the comparison localities for T_{10km}, T_{20km}, and T_{30km} by 2.4, 3.3, and 1.8 percentage points respectively (the first two results being significant at the 1 percent and the last one at 10 percent). On checking for robustness, we find that the main workers decreases by 1.8 and 3.4 percentage points for T_{R_10Km} (significant at 10 percent level) and T_{R_20Km} (significant at 1 percent level) respectively.

The decrease in main workers, is driven by a decrease in males who work as main workers. Male main workers as a percentage of total workers declines by 2.56 and 1.8 percentage points in the treated localities as compared to the comparison ones for T_{10km}, and T_{20km} respectively (significant at 1 percent level). The result is insignificant for T_{30km}. Male main workers decrease by 2.8 and 2.3 percentage points for the treated localities as compared to the comparison localities for T_{R_10Km}. and T_{R_20Km}. (both significant at 1 percent level). The categorical treatment definition results in **Figure 9** also shows that the decrease in main workers and male main workers is concentrated between 5-10km from the railway station.

The increase in sex ratio accompanied by decrease in male main workers, further supports the conjecture that male migration is responsible for both the results as women are less likely to work as main workers. The institutional context in which the Konkan Railway operates and the spatial configuration of industries is important to understand the above results. Several studies over the years have found that, apart from being male dominated, the migration from this region is remittance-based, circular and largely directed towards Mumbai with regional variations such as Bangalore and Mangalore for coastal districts of Karnataka, Gulf countries for the Muslim population in the region and Gulf and Europe for certain Christian populations in Goa (Tumbe 2012, 2015; Thorat et al. 2011; Sita and Prabhu 1989). People have been migrating much before the Konkan Railway was built, first by steamships and later using the improved road connection. Historical migration for better employment opportunities goes as far back as the 19th century in some instances.

In the context of this historical development experience, as confirmed by the key informant interviews and the increase in passenger traffic, that the people of the region experienced the arrival of the Konkan Railway on the scene as having enhanced the region's connectivity with the remainder of the nation and, most importantly, with Mumbai. Although the region is serviced by a highway connecting it to Mumbai in the north and Kerala in the south, based on the interview findings and the passenger data we could conclude that the Konkan Railway has by and large received patronage from the passengers over the highway due to several factors. The most important factors being cheaper and fixed fares, unlike seasonal fare fluctuations in bus transport, and comfort. The cheaper fares are a result of the policy of the Government of India which cross-subsidizes passenger fares using freight earrings, in order to make railway travel affordable to the majority of the Indian population (See **Table *4*** for a comparison of bus vs train fares). However, various non-monetary considerations too have a significant role to play in people’s preference for railway travel. Specifically, for the travellers, the railway provides a tangibly different experience in terms of comfort; on board-facilities such as washroom and meals; and safety which the current or an expanded highway network may not be able to match. The fact that Konkan Railway has received passenger patronage is also apparent from the frequent complaints recorded in the interviews that the villagers prefer the train but find it difficult to obtain reserved tickets, their demand for more trains to halt at the station closest to their village and suggestions for double tracking the currently single-track line to increase line capacity.

In addition, a prevalent view expressed by representatives of Panchayat who were interviewed was that the Railway did not do much for the region in terms of industrial investment, but it has significantly enhanced connectivity. We also found in our interviews, that in continuation with the earlier period, Mumbai continued to exert a strong metropolitan pull on the Konkan region. However, due to the “concentrated decentralization” of industries post-1991, apart from Mumbai, new destinations such as Surat, Goa and Raigarh, emerged as the most frequented destination for travel for work using the Konkan Railway. Chakravorty (2003) has analyzed the distribution of investment activity and industrial location in the pre and post reform period, with 1991 as point of departure and finds evidence of concentration of industrial investment in the already advanced region with dispersal within the region, a phenomenon he refers to as “concentrated decentralization”. He highlights the “emergence of India’s new industrial core – a leading edge of non-metropolitan, coastal districts that are relatively proximate to metropolitan areas”. The most important of these clusters is the corridor stretching from “south of Greater Bombay northward into southern Gujarat, and includes the districts of Ratnagiri, Raigarh, Greater Bombay, Pune, Thane (in Maharashtra), and Bharuch, Surat, and Vadodara (in Gujarat)” (p.135). The Mumbai metropolis forms the anchor of this coastal industrial cluster which has heavy concentrations of heavy industry, chemicals and petroleum, and utilities. He also records, that post 1991, investments have found new non-industrial locations such as Dakshina Kannada in Karnataka. The Konkan Railway connects the Konkan region to these industrial clusters. One could then plausibly conclude that by cutting down the distance and travel time, and by providing a cheap and safe means of transport, the Konkan Railway has not only amplified the already existing pattern of travel in the region, but also enhanced the available choice of destinations for seeking employment by connecting the region to the rest of country.

The increase in sex ratio accompanied by decrease in male main workers, further supports the conjecture that male migration is responsible for both the results as women are less likely to work as main workers. Migration studies helps us in understanding some of the causal mechanisms through which infrastructure facilitates migration. Deshingkar and Grimm (2005) note that a “major hindrance in gaining more fully from the many different possibilities for livelihood enhancement through migration is the difficulty in maintaining social and financial links” (p.54). They suggest that “better infrastructure, transport services and communication networks can help to keep social links alive” (p.54). We find evidence of this in our key informant interviews where a common observation across sub-districts was that the Konkan Railway by providing a cheap, and comfortable means of transport has encouraged people to make more frequent trips for business, religious and familial reasons. The interviewees pointed out that, whereas, earlier migrants and those settled in Mumbai would visit their native villages in Konkan only once or twice a year, the convenience, comfort and lower fares of the Railway has made possible more frequent trips. It is possible to conjecture that by improving accessibility, the Konkan Railway has made it even more easier for migrating male household members to retain ties with their native places and enables them to function more easily from more than one home. It is also possible to conjecture that strengthening the transport system might result in more outmigration, if it is not accompanied by other inputs to create more avenues for employment in the place of residence.

We also find an increase in population, crude workforce participation rate (CWPR) and other (main) workers in localities closer to the railway station. The overall population increases by 158 persons (significant at 1 percent level), the rural population increases by 102 (significant at the 1 percent level) and the urban population by 3665 persons (significant at 10 percent) for treated localities as compared to the comparison localities for T_{10km}. The results for rural and urban population is insignificant for T_{20km} and T_{30km}. The categorical treatment definition results in **Figure 4** shows that the increase in total population (287 persons), rural (127 persons) and urban population (8218 persons) is concentrated between 0-5km from the railway station.This is the only distance band where a significant effect can be detected. The effect on population seems to be negatively related to the distance from the station. For distances beyond 10km, we even find a negative coefficient, although a null effect cannot be rejected for all assessed distance bands. On checking the robustness of these findings , we find that the population increases by 111 persons and rural population by 79 persons (both results significant at 1 percent level) for T_{R_10Km} further corroborating that the closeness to the railway station is associated with increased population (See Table 4). The result is not significant for urban population.

The increase in population is complemented by an increase in the CWPR in the treated localities as compared to the comparison localities for $T_{10km,}$, and T_{20km} by 1.2 and 1.5 percentage points respectively (significant at 1 percent level). The result is insignificant for $T_{30km,}$ The categorical treatment results for CWPR is positive but not significant for treatment bands 0-5, 5-10 and 10-20km. It is negative and significant at 1 percent level for distance of 20-30km from the station. On checking the robustness of these findings against a treatment definition T_{R_10Km} and T_{R_20Km} we find that the CWPR increases by 1.6 and 2.33 percentage points (significant at 1 percent level) respectively.

While on the one hand the CWPR has increased, on the other hand, the percentage of main workers, as pointed out earlier, has decreased for treated localities as compared to the comparison localities for $T_{10km,}$ and T_{20km}. The increase in CWPR is therefore driven by an increase in the share of marginal workers, defined as those who work for less than six months a year, to total workers (total workers being the sum of marginal and main workers). Whereas the increase in sex ratio is indicative of outmigration or remittance-based migration, the decision of people to relocate to better connected localities to access work opportunities through increased commuting outside the place of residence, might plausibly be driving the increase in population and marginal workers close to the railway station. We find evidence of this in the key informant interviews.

Panchayat members we interviewed drew our attention to a large number of frequent short distance travellers and daily commuters who use the Konkan Railway for more local, inter-district and inter-state travel for work. For example, interviewees in Uttara Kannada district, pointed out that males from their villages seasonally migrate to Kerala and Goa to work in fishing boats, whereas females migrate to work in fish processing factories. These accounts can be corroborated by various studies and newspaper articles which refer to the heavy dependence of the fish processing sector in Kerala and Goa on migrant workforce from a number of states in India including coastal Karnataka (Hiran 2017; Peter and Narendran 2017; Sathiadhas and Prathap 2009). The interviewees point out that that railway connectivity to Kerala and Goa via the Konkan Railway has provided an easy means of commute to these seasonal migrants. Interviewees in the southern sub-districts of Sindhudurg, such as Kudal and Sawantwadi and in northern sub-districts of Uttara Kannada such as Karwar and Ankola either commute daily to Goa to work in pharmaceutical factories, industrial estates, or as hawkers and street vendors or stay in Goa for the week and return on weekends.[11] According to the interviewees, individuals commute to work rather than migrate because of the higher cost of living in Goa. Some interviewees in Goa pointed out that people commute to work daily within Goa by train, for example from Thivim to Madgaon (a distance of approximately 50 to 65 km,) which is the commercial capital of Goa and its second biggest city by population. Similarly, interviewees in Raigarh district, highlighted that people from the villages also work and live in Navi Mumbai and commute frequently to their native villages. In addition, the other category of workers using trains for daily or frequent commutes are government officials and bank employees.

Our findings are in line with and contribute to the larger empirical research on how transport connectivity affects commuting and migration decisions. Studies have found that a large numbers of workers in India commute across rural-urban boundaries every day without changing their place of residence (Sharma and Chandrasekhar 2014; Deshingkar, Rao, Akter and Farrington 2009). The phenomenon of commuting by workers has also been observed in other developing countries such as Bangladesh, Indonesia, Nigeria and Tanzania (See for example, Bah et al., 2003; Baker, 1995; Fafchamps and Shilpi, 2003). Bah et al find that in south-eastern Nigeria, commuting to the regional urban centres of Aba and Port Harcourt is encouraged by the efficient and cheap state-subsidized transport system (Bah et al. 2003). For the state of Andhra Pradesh in India, Deshingkar (2010), finds that belonging to a well-connected village in a prosperous region increases the likelihood of commuting. They explain the dramatic increase in commuters in Andhra Pradesh to the growing road network, improved communications and rapid rate of urbanization, especially the growth of small towns. Based on National Sample Survey Organization (NSSO) data, Sharma and Chandrasekhar (2014) estimate that in the year 2009–10, 12.42 million workers engaged in non-agricultural activity via daily commutes outside their place of residence (Sharma and Chandrasekhar 2014). Out of this 8.05 million were rural-urban commuters and 4.37 million urban–rural commuters. Sharma and Chandrasekhar (2014) also point out that "individuals living closer to the city and with transport connectivity will try to take advantage of the wage gradient and miniscule rents in rural areas by commuting to the nearby urban areas" (p. 155, also see Baker 1995).

[11] Unreserved passenger trains such as the Karwar-Pernem DEMU, Mangalore-Madgaon passenger train, and Ratnagiri-Madgaon passenger train cater to these commuters. Besides there a several express trains on this route.

Table 6: DID Coefficients for Binary Treatment definitions

	Binary Treatment														
	Population	Urban Population	Rural Population	Sex Ratio	CWPR	Main workers	Main Workers Male	Culti vators	Agri. labour	HHIW	Other workers	Forest Land	Culti-vated Area	Non-agri. Area	Cult-ur able Waste land
treat cutoff = 10	157.97***	3,665.44*	102.43***	18.16***	1.20***	-2.37***	-2.56***	-1.35	-0.46	-0.22	2.04***	4.34	-29.69***	6.31	66.59***
	(33.47)	(1,963.24)	(19.49)	(5.77)	(0.45)	(0.88)	(0.63)	(0.88)	(0.81)	(0.15)	(0.75)	(8.67)	(9.20)	(6.44)	(7.62)
Control group baseline mean	904.4	13840	791.6	1107	48.88	87.32	54.61	58.86	21.02	1.037	19.08	260	208.4	118.1	132.3
treat cutoff = 20	65.08*	2,031.64	25.97	-0.21	1.46***	-3.34***	-1.83***	-1.69*	2.34***	-0.30*	-0.36	-17.05*	-31.78***	7.27	0.42
	(35.46)	(2,718.59)	(20.50)	(6.11)	(0.48)	(0.93)	(0.66)	(0.93)	(0.85)	(0.16)	(0.79)	(9.11)	(9.66)	(6.76)	(8.04)
Control group baseline mean	822.5	11791	732.5	1078	49.28	87.71	56.61	56.80	23.45	1.026	18.73	289.7	207.1	103.9	109
treat cutoff = 30	-21.53	2,516.63	-23.68	-10.08	-0.66	-1.83*	0.69	-4.15***	3.77***	-0.15	0.52	-43.07***	20.02*	-0.75	-74.64***
	(41.69)	(3,632.11)	(24.05)	(7.18)	(0.56)	(1.10)	(0.78)	(1.09)	(1.00)	(0.19)	(0.93)	(10.68)	(11.34)	(7.93)	(9.39)
Control group baseline mean	797.4	12326	710.5	1040	49.26	88.64	59.21	54.69	25.99	1.057	18.26	290.9	209.6	85.72	84.66
Observations	15,473	244	15,229	15,451	15,452	15,451	15,451	15,441	15,441	15,441	15,441	15,229	15,229	15,227	15,227
R-squared	0.15	0.40	0.02	0.11	0.03	0.11	0.05	0.30	0.05	0.03	0.30	0.01	0.01	0.02	0.11
Number of localities	7,797	170	7,714	7,797	7,797	7,797	7,797	7,797	7,797	7,797	7,797	7,714	7,714	7,714	7,714

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Treated if distance from the Konkan Railway station (treat cutoff) is <=xkm and untreated if distance from the Konkan Railway station is >xkm but less than 100km

The results are based on estimation equation [1] in section 4.4.1

CWPR=Crude-workforce participation rate, Agri labour=Agricultural labour, HHIW=Household Industry Workers; Non Agri area= Area not under agricultural uses.

Table 7: DID Coefficients for Robustness checks and categorical treatment

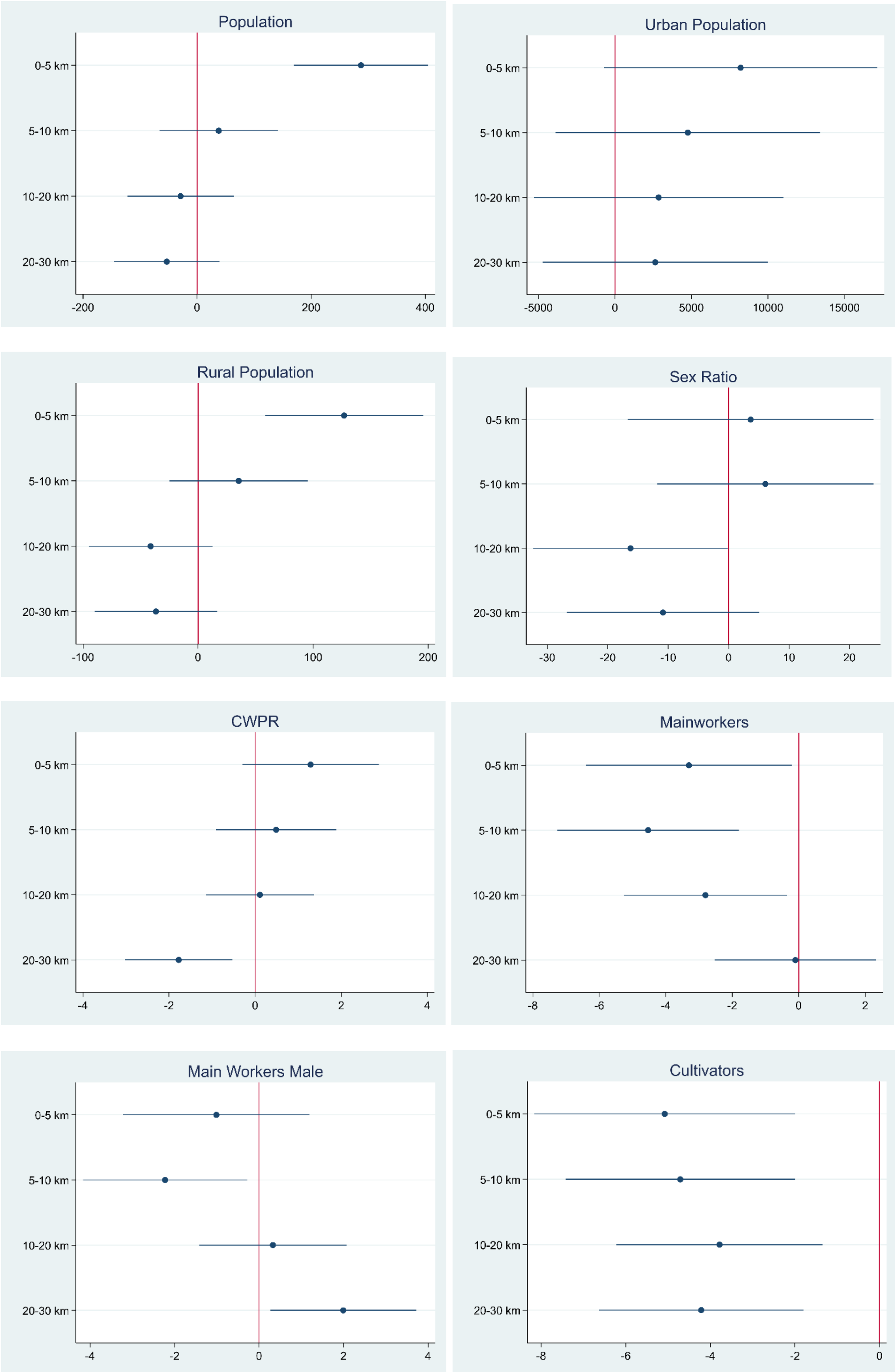
VARIABLES	Population	Urban Population	Rural Population	Sex Ratio	CWPR	Main workers	Main Workers Male	Culti-vators	Agri-cultural labour	HHIW	Other workers	Forest Land	Culti-vated Area	Non Agri Area	Cultur-able Waste-land
Robustness Checks															
treat cutoff 10km	110.80***	2,464.65	79.50***	21.64***	1.58***	-1.75*	-2.80***	-0.24	-1.97**	-0.09	2.30***	20.67**	-21.22**	2.45	72.21***
	(40.72)	(2,341.53)	(23.80)	(6.40)	(0.50)	(1.01)	(0.69)	(0.98)	(0.86)	(0.17)	(0.86)	(9.21)	(10.48)	(7.50)	(9.04)
Control group baseline mean	941.4	13763	824.8	1160	49.29	85.18	50.20	62.36	15.69	0.993	20.96	242	201.2	134.3	153.2
treat cutoff 20km	-35.56	-1,705.45	-32.84	-0.73	2.33***	-3.44***	-2.31***	-0.26	1.31	-0.13	-0.92	5.20	-31.21***	2.13	-12.35
	(46.82)	(3,662.01)	(27.16)	(7.36)	(0.57)	(1.16)	(0.80)	(1.12)	(0.98)	(0.20)	(0.99)	(10.50)	(11.94)	(8.55)	(10.36)
Control group baseline mean	823	10361	742.6	1139	50.18	84.73	51.29	60.68	17.04	0.953	21.32	282.7	195.2	118.9	124.8
Observations	11,889	213	11,676	11,869	11,869	11,869	11,869	11,861	11,861	11,861	11,861	11,676	11,676	11,674	11,674
R-squared	0.15	0.41	0.01	0.14	0.02	0.11	0.04	0.34	0.07	0.03	0.32	0.01	0.01	0.01	0.10
No. of localities	6,002	151	5,933	6,002	6,002	6,002	6,002	6,002	6,002	6,002	6,002	5,933	5933	5,933	5,933
Categorical Treatment															
0-5 km	287.29***	8,218.12*	127.00***	3.65	1.29	-3.30**	-1.01	-5.08***	3.32**	-0.40	2.16	-30.51*	-12.59	6.56	-4.40
	(60.07)	(4,475.21)	(35.03)	(10.37)	(0.81)	(1.58)	(1.12)	(1.57)	(1.45)	(0.27)	(1.34)	(15.59)	(16.53)	(11.58)	(13.63)
5-10 km	37.92	4,764.59	35.35	6.07	0.49	-4.53***	-2.22**	-4.71***	3.35***	-0.35	1.70	-38.90***	-15.06	5.77	-13.59
	(52.94)	(4,331.74)	(30.66)	(9.14)	(0.71)	(1.39)	(0.99)	(1.39)	(1.27)	(0.24)	(1.18)	(13.64)	(14.46)	(10.14)	(11.93)
10-20 km	-28.96	2,857.38	-41.21	-16.24**	0.11	-2.81**	0.33	-3.78***	4.85***	-0.24	-0.82	-46.95***	4.03	2.20	-85.62***
	(47.51)	(4,083.68)	(27.47)	(8.21)	(0.64)	(1.25)	(0.89)	(1.25)	(1.14)	(0.22)	(1.06)	(12.22)	(12.96)	(9.08)	(10.68)
20-30 km	-53.13	2,633.00	-36.59	-10.86	-1.77***	-0.10	1.99**	-4.22***	3.04***	0.01	1.17	-41.92***	46.07***	-5.66	-88.67***
	(47.03)	(3,685.74)	(27.17)	(8.12)	(0.63)	(1.24)	(0.88)	(1.23)	(1.13)	(0.21)	(1.05)	(12.09)	(12.82)	(8.98)	(10.57)
Observations	15,473	244	15,229	15,451	15,452	15,451	15,451	15,441	15,441	15,441	15,441	15,229	15,229	15,227	15,227
R-squared	0.16	0.45	0.03	0.11	0.03	0.11	0.05	0.30	0.05	0.03	0.30	0.01	0.01	0.02	0.12
No. of localities	7,797	170	7,714	7,797	7,797	7,797	7,797	7,797	7,797	7,797	7,797	7,714	7,714	7,714	7,714

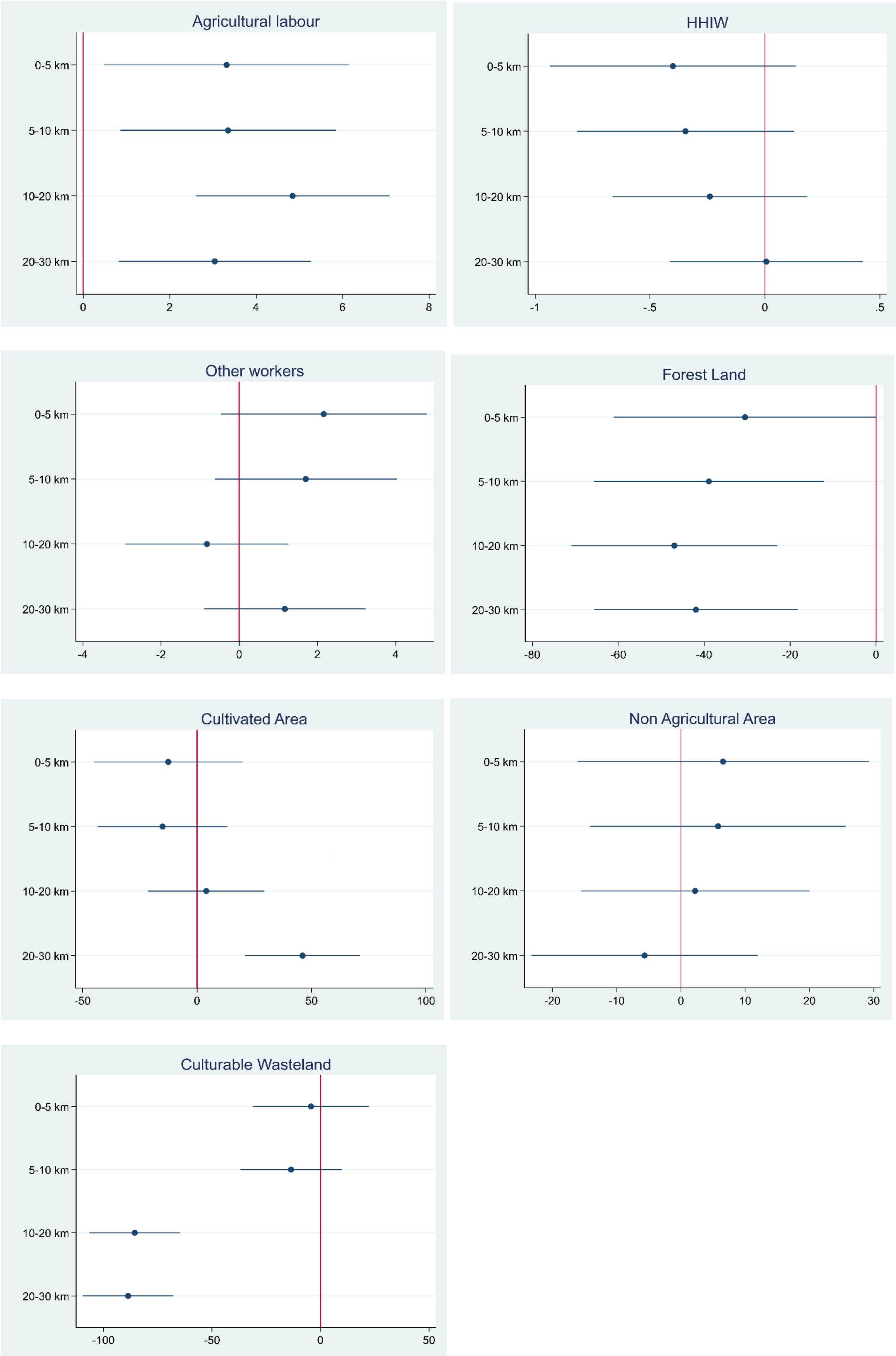
Standard errors in parentheses; ***p<0.01, ** p<0.05, * p<0.1

Note: Here for robustness checks the treatment is defined as treated if distance from station<=xkm Untreated if >xkm & <=50km. The results are based on estimation equation [1] in Section 4.4.1. The categorical treatment estimation is based on estimation equation [2] in Section 4.4.2.

CWPR=Crude-workforce participation rate, HHIW=Household Industry Workers; Non Agri area= Area not under agricultural uses.

Figure 9: Categorical Treatment Results




Agricultural labour
0-5 km
5-10 km
10-20 km
20-30 km
0
2
4
6
8
HHIW
0-5 km
5-10 km
10-20 km
20-30 km
-1
-.5
0
.5
Other workers
0-5 km
5-10 km
10-20 km
20-30 km
-4
-2
0
2
4
Forest Land
0-5 km
5-10 km
10-20 km
20-30 km
-80
-60
-40
-20
0
Cultivated Area
0-5 km
5-10 km
10-20 km
20-30 km
-50
0
50
100
Non Agricultural Area
0-5 km
5-10 km
10-20 km
20-30 km
-20
-10
0
10
20
30
Culturable Wasteland
0-5 km
5-10 km
10-20 km
20-30 km
-100
-50
0
50

Our results which follow from the mobility of labour can be contrasted with those which estimate the effects of infrastructure in China, where the government has had a long-standing policy of restricting migration from rural to urban areas. Wang and Wu (2015) find an insignificant effect of the railway infrastructure on population in counties along the railway, and attribute the result to a strictly enforced Hukou system, a kind of household registration system, which restricts permanent migration and thereby labour mobility. However, they add the caveat that is it possible that the railway attracted more people to the railway counties, but being temporary migrants, who do not have local Hukou, they did not get reflected in the official population statistics. Banerjee et al. (2012). also find only small positive causal effect of access to transport networks, on per capita GDP levels across sectors and attribute the result to a lack of factor mobility, both labour and capital, in the Chinese setting. They also provide an alternative explanation for the effects, wherein they argue that the infrastructure might have brought "sizeable benefits for the economy as a whole, but the localization of the gains (and the overall level of the gains) was limited by the lack of factor mobility" (p.32-33). Zhou and Logan (2007) and Baum-Snow et al.(2017) too observe that the institutional barriers to the mobility of labour and capital in the Chinese context meant that roads and railroads in 1990 could not be used for commuting nor influence factory relocation to suburbs.

In general, we would also expect the localities in close proximity to the railway station to perform better because of enhanced accessibility and due to the sheer presence of the railway station infrastructure which might induce indirect and wider economic effects. In line with this, for T_{10km} we find that an increase in other (main) workers, defined as those working in non-household industry and services for more than six months in a year, as percentage of total main workers by 2 percentage points (at 1 percent level of significance). The result is insignificant for all other treatment definitions. The categorical treatment results are positive but not significant for all treatment bands. For robustness check treatment definition, T_{R_10Km}, we find that it increases by 2.3 percentage points (at 1 percent level of significance) for the treated localities for T_{R_10Km} and is insignificant for T_{R_20Km} (See Table 4).

When it comes to other occupational categories for main workers, we find that main household industry workers as percentage of total main workers declines by approximately 0.3 percentage points for T_{20km} (at significance level of 10 percent). The result is insignificant for other binary treatment definitions. The result for the percentage of main cultivators to total main workers is insignificant for $T_{10km.}$ It falls by 1.7 and 4.1 percentage points for, , $T_{20km,}$ and T_{30km} respectively (the results being significant at 10 percent and 1 percent level respectively). For main agricultural labourers as a percentage of total workers, the results are insignificant for $T_{10km..}$ It increases by 2.3 and 3.8 percentage points for $T_{20km,}$ and $T_{30km.}$ respectively (the results being significant at the 1 percent level). On checking for robustness, we find the results for main cultivator is insignificant for T_{R_10Km} and $T_{R\_20Km.}$ For agricultural labour it declines by 2 percentage points (significant at 5 percent level) for T_{R_10Km} and is insignificant for $T_{R\_20Km.}$ Like the binary treatment definition, the graph for the outcome main cultivators and agricultural labour for categorical treatment estimation in **Figure 4** shows a significant decline in main cultivators and a rise in agricultural labour for different distance bands between 0-30km. the decline for cultivator is strongest in 0-5km treatment band and the increase in agricultural labour is strongest in 10-20km distance band.

The simultaneous decline in cultivators and increase in agriculture labour may occur due to a combination of factors. The move away from agriculture to other productive activities with the expansion of rural non-farm activities and access to non-farm employment outside the place of residence may contribute to the decline in cultivators (Thomas, 2014). As the decline in cultivators for our treated localities is accompanied in most instances with a rise in agricultural labour, another plausible explanation is that the residents as well as migrants who own farming land in the village choose to informally lease out land to landless agricultural labourers under various forms of tenancy.[12] This phenomenon is exacerbated by the fragmentation and sub-division of landholdings, the diminishing profitability from agriculture and increasing cost of hiring agricultural labour in the Konkan region. In fact, some Panchayat members we interviewed mentioned that landowners who were residing in Mumbai either lease out the land to landless agricultural labourers for cultivation on a sharecropping arrangement.

9.1.2 Land use change using Census Data

The results of the land use change also support some of the findings from workforce composition. The workforce composition results show that the extent of rise in agricultural labour was more than the accompanying decline in cultivators. This is also corroborated by the decline in cultivated area in the treated localities as compared to comparison ones. Cultivated area declines by 29.7 and 31.8, hectares for $T_{10km,}$ and $T_{20km,}$ (at the 1 percent significance level). It increases by 20 hectares for T_{30km} (10 percent significance level) .Culturable wasteland, that is land not cultivated in the last five years is also on the rise in the treated localities closer to the railway station. For T_{10km} the culturable wasteland increases for treated localities as compared to comparison ones by 67 hectares. The result is insignificant for T_{20km} and it decreases for treated localities for T_{30km} . The cultivated area declines for T_{R_10Km} and T_{R_20Km} as well. Whereas, for culturable wasteland it increases by 72 hectares for T_{R_10Km} and is insignificant for T_{R_20Km} . Hence, the treatment cutoff from which the coefficient for areas of culturable wasteland ceases to be positive and the one for cultivable land ceases to be negative are slightly different. For the categorical treatment definition, we only find significant results for the distance band 20-30km where the cultivable area increases by 46.1 percentage points (significant at 1 percent) and culturable wasteland decreases by 88.7 percentage points.

Forest area as recorded in the census shows no significant change for treated localities as compared to comparison ones for $T_{10km,.}$ Forest area declines by 17, and 43 hectares for, $T_{20km,}$ and T_{30km} respectively (significant at 10 and 1 percent level). The categorical treatment results show an decrease in forest land at different distance bands between 0-30km, whereas the robustness check shows that forest area increases by 20.7 hectares (significant at 5 percent) for T_{R_10Km} and is not significant for $T_{R\_20Km.}$ The census data on forest area captures forest cover within the village boundaries. However, in the case of the railway, it is important to consider land use change along the linear infrastructure, as the establishment and maintenance of railway lines cause direct loss of vegetation cover on either side on the line. Environmental deterioration is likely to be more severe for areas along the line than those away. Land use change along the railway line is captured using satellite data in Section 10.

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[12] According to 59th round of NSSO, about 36 percent of the tenant farmers are landless, while nearly 56 percent of the tenant households are marginal land owners, having less than one hectare land. *Report of the Expert Committee on Land Leasing*, 2016)

9.1.3 Continuous treatment

In the previous section, the distance to the nearest railway station in kilometres after inauguration of Konkan Railway, was converted into a dichotomous variable and different distance bands. Now we use distance directly to assess a continuous treatment variable. Since we have distance from the nearest railway station only at endline, our estimates are based on equation [3] in Section 6.5.4. The results are presented in ***Table 8***.The interpretation of results of the quadratic functional form is less straightforward than for the previous analyses as the coefficient of the simple distance and the quadratic distance have to be jointly considered. Of the fifteen outcome indicators related to population, workforce composition and land use, nine show a significant coefficient for the quadratic term. A priori, one expects the coefficient of the simple distance to be the opposite of the coefficients for the binary treatment indicators: as treatment is defined by the closeness to Konkan Railway stations, a positive coefficient for a binary treatment indicator implies a negative coefficient for the distance variable. Apart from culturable wasteland, this is actually the case for all indicators when considering the binary treatment indicator $T_{10km.}$ Seven of these variables show significant coefficients: the CWPR, the share of main worker, share of male main workers, the share of main cultivators, share of main other workers and areas under forest land and culturable wasteland.

9.2 Additional heterogeneity analyses

9.2.1 Station Agglomerations as treated

Table 9 summarizes the estimation results when the station agglomerations are treated. We find that the total population, rural and urban population has increased by 1239, 373 and 6575 persons (1 percent significance) in the treated station agglomerations as compared to non-station localities. The sex ratio increases by 31 females for treated station agglomerations (5 percent significance). The plausible explanation for this phenomenon is the decision of people to relocate to better connected localities from remote localities and increased remittance-based male migration from better connected localities. These findings corroborate our findings from the binary treatment specifications T_{10km} and the robustness check $T_{R\_10Km,}$ i.e. that the increase in population and sex ratio is concentrated in close proximity to the railway stations. The results are not significant for all other outcomes. This may be due to the small number of observations in the treatment group: while under this definition, only 155 localities are considered as treated, the number of treatment observations is 1904 for the binary definitions T_{10km}.

9.2.2 Results with highway interaction term

In all the earlier DID specifications, we controlled for the distance from the highway by interacting it as a continuous variable with post-treatment time-period dummy. In order to test for heterogeneous effects of railway access depending on the simultaneous closeness to the highway, we split the distance from the highway into three different bands (0 to 10, 10 to 20, 20-30 km) and interact them in separate estimations with the treatment dummy (T_{10km}) and post-treatment time-period dummy (see Section 6.5.4.5). The results based on estimation equation [4] is presented in Table 9 below.

Table 8: Summary Results: Continuous Treatment 1991-2011

	Continuous Treatment														
	Pop ulation	Urban Pop- ulation	Rural Pop- ulation	Sex Ratio	CWPR	Main workers	Main Workers Male	Culti vators	Agri- cultural labour	HHIW	Other workers	Forest Land	Culti- vated Area	Non Agri Area	Cultur able Waste land
post x distance from railway station	-3.37	-196.51	-1.17	-0.19	-0.07**	0.15**	0.08*	0.18***	-0.03	-0.00	-0.15***	1.69***	0.02	-0.49	1.30**
	(2.32)	(205.19)	(1.35)	(0.40)	(0.03)	(0.06)	(0.04)	(0.06)	(0.06)	(0.01)	(0.05)	(0.61)	(0.63)	(0.46)	(0.53)
post x (distance from railway station)2	0.08***	2.59**	0.04***	0.00	0.00	-0.00***	-0.00***	-0.00***	0.00	-0.00*	0.00***	-0.01***	0.00	0.00	0.00
	(0.02)	(1.20)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	15,595	245	15,350	15,573	15,574	15,573	15,573	15,563	15,563	15,563	15,563	15,350	15,350	15,348	15,348
R-squared	0.15	0.43	0.03	0.11	0.03	0.11	0.05	0.29	0.05	0.03	0.30	0.00	0.01	0.02	0.11
Number of locality	7,858	171	7,775	7,858	7,858	7,858	7,858	7,858	7,858	7,858	7,858	7,775	7,775	7,775	7,775

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Note: The results for the continuous treatment is based on the estimation equation [3] in Section 4.4
CWPR=Crude-workforce participation rate, HHIW=Household Industry Workers; Non Agri area= Area not under agricultural uses

When the treated localities are within 10 km of the highway as well as the railway station, we find that for the treated localities, the population, urban population, rural population and sex ratio rises by 136, 3209, 90 persons and 10 females respectively (See Table 9). Comparing these estimates to T_{10km}, which shows an increase in population, urban population, rural population and sex ration by 158, 3665, 102 persons and 18 females respectively, we can plausibly conclude that the being closer to the railway station has a greater positive effect on these outcomes. This is also in line with the explanation we provided previously in Section 9.1.1 that the railway has emerged as the preferred mode of transport for migrants and commuting workers and has made it increasingly easier for them to pursue multi-local livelihood strategies.

When the treated localities are within 10km of the railway station but between 10-20kms from the highway, then for the treated localities the population and rural population rises by 202 and 80 persons respectively (See Table 9). The result is insignificant for urban population and sex ratio. When the treated localities are within 10km of the railway station but between 20-30kms from the highway, then the results are insignificant for all variables.

When the treated localities are within 10 km of the highway and the railway, we find that for the treated localities, CWPR is insignificant, whereas for T_{10km} it increases by 1.2 percent for treated localities. For the treated localities within 10 km of the highway as well as the railway, percentage of main workers to total workers falls by 1.6 percentage points, whereas for $T_{10km,}$ it falls by 2.4 percentage points; for main cultivators to total main workers it falls by 2.8 percentage points whereas for T_{10km} it is insignificant. For other main workers to total main workers it increases for treated localities within 10 km of the highway as well as the railway as compared to comparison localities by 3.9 percentage points, whereas for T_{10km} it rises by 2 percentage points for treated localities as compared to comparison ones.

On the one hand, like for the population, the effect is stronger for percentage of main workers to total workers when treated localities are closer to the railway, than when they are closer to the railway and highway (within 10kms). On the other hand, the rise in other workers is sharper for treated localities that are close to both the highway and railway (within 10 km of the highway and the railway) than for those which are close to the railway (within 10 kms). The results are insignificant for all outcomes, when the treated localities are within 10km of the railway station but between 10-20kms or between 20-30kms from the highway. For the treated localities that are within 10 km of the highway and the railway, the cultivated area falls and culturable area rises as compared to comparison localities but at a lesser extent than for T_{10km}.Like for the population, the effect is stronger when treated localities are closer to the railway, than when they are closer to the railway and highway (within 10kms). The results are insignificant for both the treatment definitions for forest area and area not under agricultural use. The results are insignificant for all outcomes, when the treated localities are within 10km of the railway station but between 10-20kms or between 20-30kms from the highway and 10 km from the railway station.

Based on these results we could plausibly conclude that the closeness to the railway station is more strongly related with changes in our outcome variables. This may be because railways unlike highways stimulate changes which are more concentrated only along the nodal location rather than the entire alignment.

Table 9: DID Coefficient additional heterogeneity analysis

	Pop	Urban Pop	Rural Pop	Sex Ratio	CWPR	Main workers	Main Workers Male	Culti vators	Agri labour	HHIW	Other workers	Forest Land	Culti-vated Area	Non Agri Area	Cultur able Waste land
Highway Interaction															
post distance highway below 10 km x distance railway station 0-10km	135.60***	3,208.90*	90.43***	10.22*	0.34	-1.63**	-0.68	-2.82***	-1.15	0.07	3.90***	-3.86	-21.52**	6.80	48.59***
	(30.99)	(1,650.33)	(18.07)	(5.34)	(0.42)	(0.82)	(0.58)	(0.81)	(0.75)	(0.14)	(0.69)	(8.05)	(8.53)	(5.97)	(7.08)
Observations	15,471	244	15,227	15,449	15,450	15,449	15,449	15,439	15,439	15,439	15,439	15,227	15,227	15,225	15,225
R-squared	0.15	0.41	0.03	0.11	0.03	0.11	0.04	0.29	0.05	0.03	0.30	0.00	0.01	0.02	0.11
No of Localities	7,796	170	7,713	7,796	7,796	7,796	7,796	7,796	7,796	7,796	7,796	7,713	7,713	7,713	7,713
post x distance highway 10-20 km x distance railway station 0-10km	202.04***	5,075.58	80.25**	-3.72	1.60	-0.62	-2.08	1.89	-2.07	-0.29	0.47	-4.87	-16.63	0.79	29.15
	(58.44)	(3,247.95)	(40.47)	(14.37)	(1.10)	(2.06)	(1.49)	(2.12)	(2.01)	(0.33)	(1.77)	(23.60)	(23.69)	(14.42)	(19.38)
Observations	11,161	104	11,057	11,143	11,144	11,143	11,143	11,135	11,135	11,135	11,135	11,057	11,057	11,057	11,057
R-squared	0.15	0.41	0.03	0.10	0.03	0.10	0.06	0.23	0.03	0.02	0.23	0.00	0.00	0.02	0.12
No of Localities	5,626	69	5,584	5,626	5,626	5,626	5,626	5,626	5,626	5,626	5,626	5,584	5,584	5,584	5,584
post x distance highway 20-30 km x distance railway station 0-10km	-163.39		-94.80	34.63	-1.09	-10.91	-1.60	-1.93	2.11	1.70	-1.88	15.46	-15.32	-27.22	-27.04
	(181.14)		(122.92)	(50.19)	(3.85)	(7.05)	(5.28)	(7.43)	(7.13)	(1.13)	(6.19)	(90.20)	(87.43)	(52.04)	(60.41)
Observations	8,585	79	8,506	8,578	8,579	8,578	8,578	8,570	8,570	8,570	8,570	8,506	8,506	8,506	8,506
R-squared	0.10	0.44	0.05	0.07	0.04	0.09	0.07	0.19	0.02	0.02	0.21	0.01	0.00	0.03	0.12
No of Localities	4,327	51	4,292	4,327	4,327	4,327	4,327	4,327	4,327	4,327	4,327	4,292	4,292	4,292	4,292
Station Agglomeration															
treat =station agglomeration	1,239.33***	6,574.97***	373.29***	30.63**	0.98	-0.60	-0.83	2.82	-2.05	-0.09	-0.68	14.10	12.04	1.24	31.46
	(81.61)	(1,781.69)	(51.22)	(14.26)	(1.12)	(2.18)	(1.55)	(2.17)	(2.00)	(0.38)	(1.85)	(23.23)	(24.21)	(17.43)	(20.38)
Control group baseline mean	1027	13218	917.4	1116	47.92	87.22	54.15	58.30	19.55	1.169	20.98	220.1	212.4	118.5	130.6
Observations	15,595	245	15,350	15,573	15,574	15,573	15,573	15,563	15,563	15,563	15,563	15,350	15,350	15,348	15,348
R-squared	0.17	0.49	0.03	0.11	0.03	0.11	0.05	0.29	0.05	0.03	0.30	0.00	0.01	0.02	0.10
No. of localites	7,858	171	7,775	7,858	7,858	7,858	7,858	7,858	7,858	7,858	7,858	7,775	7,775	7,775	7,775

Note: The results for the highway interaction is based on the estimation equation [4] in Section 6.5.4.5.The results for the station agglomeration is based on estimation equation [1] in Section 6.5.4.3, where the treatment is a dummy variable which takes the value 1 if the locality is a station agglomeration and 0 otherwise.
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1,

9.3 Results and discussion for 1991-2001

Previous analyses focus on the average railway effect more than a decade after the railway began full operations. While the complete Konkan Railway line of 760 km became fully operational in 1998, from 1993 onwards the Konkan Railway was opened up for traffic in phases from each end, which might lead to some short-term impact between 1991-2001 (See Section 3.2). Moreover, the construction of such a large infrastructure project, could have stimulated the local economy. Also, it is possible that people's expectations could have changed in response to the approval of the project, which may have induced early labour migration. For the binary treatment, continuous treatment, robustness checks and station agglomeration estimation results for 1991-2001, please refer to the Appendix. We briefly summarize the findings here.

Similar to 1991-2011, we find that between 1991 and 2001, as well, the population increased in the treated localities as compared to the comparison ones for $T_{10km,}$ with the rise being sharper between 1991-2011 period. The robustness checks for $T_{R\_10Km,}$ for 1991-2001 further corroborate that the increase in population is concentrated in close proximity to the railway station. Same is the case when we consider station agglomerations as treated. The impact on sex ratio however differs between 1991-2001 and 1991-2011. Whereas for the longer time-period between 1991-2011, we find an increase in sex ratio for treated as compared to comparison localities for $T_{10km,}$ and T_{R_10Km} (results being significant at the 1 percent). For 1991-2001, we find no significant change in sex ratio for $T_{10km,}$ and $T_{R\_10Km.}$ This indicates that remittance-based migration in response to improved transport infrastructure is slow to materialize.

Like for 1991-2011, for 1991-2001 the increase in population is complemented by an increase in the crude work force participation in the treated localities as compared to the comparison localities for .but to a lesser extent. For 1991-2001, the percentage of main workers to the total population, has decreased for treated localities as compared to the comparison localities for, $T_{20km,}$ The results are insignificant for T_{10km}While the changes in population and crude workforce composition had materialized to some extent between 1991-2001, the changes in occupational categories of main workers has been more slow to materialize. Whereas we find an increase in percentage of other workers between 1991-2011 for $T_{10km.}$, between 1991-2001, we find no significant change. Unlike between 1991-2011, which saw a decline in cultivators and either no change or increase agricultural labour, when it comes to occupational categories for main workers, percentage of cultivators to total main workers rises for treated localities for $T_{10km,}$ while for agricultural labour is either insignificant or an increase. The percentage of household industry workers declines in both the time periods for the binary treatment specification T_{10km} and T_{20km}, with decline being shaper in 1991-2001 than 1991-2011. When it comes to land use changes, between both 1991-2001 and 1991-2011, we see a decline in cultivated area and rise in culturable waste area for the treated localities, with the magnitude of the decline higher in the former time-period.

10. Land use change using Satellite images

10.1 Descriptive Statistics using Landsat and LISS III Data sets

The descriptive statistics of the entire study area were obtained by enumerating the area of the individual classes in classified outputs for the years 1991, 2003 and 2014. The area figures shown in Table 10 are in sq. km for the treatment and comparison regions and the entire study area.

Table 10: Descriptive Statistics from Hybrid Classification method

Year		1991	2003	2014
Open Space (in sq.km)	Treatment	396.8	585.3	739.2
	Control	399.6	484.02	554.3
	Study Area	7901	13360	14436
Water Body (in sq.km)	Treatment	56.03	45.9	52.7
	Control	26.9	14.4	20.2
	Study Area	1292	1053	1453
Forest Cover (in sq.km)	Treatment	728	455	832
	Control	1163.3	936	1311.8
	Study Area	30062	21736	29630
Agricultural Land (in sq.km)	Treatment	1158.7	1166.2	496.9
	Control	796.6	895	329.9
	Study Area	20282	22163	10711
Note: The total area of all LULC types in the region might differ from year to year due to presence of cloud cover.				

There is a growth in the Open Spaces throughout the treatment and comparison regions as well as for the study area in intermediate and final years of analysis. This growth is approximately 199 sq. km. in the treatment region and 84 km^2 in the comparison region between 1991 and 2003. In the study area, open spaces grow to 5459 km^2 which is 1.7 times the area of open spaces in the base year. The same trend is maintained between 2003 and 2014 with open space growth being 154 km^2, 70 km^2. and 1076 km^2 in the treatment, comparison and study areas respectively. Thus, the net area of open spaces in the entire region is almost 1.8 times its value in the base year.

Water bodies do not show a change of more than 10 km^2 between the base, intermediate and final years of analysis in both, the treatment and the comparison regions. 2003 reflects a drop in the water bodies in the study area. However, in the final year, there is a significant increase in the overall area of the water bodies over 2003.

Forest Cover shows a drop between the base and intermediate years by 37% in the treatment region and 19% the control region. In the entire region, the drop in forest cover in 2003 is 8326 km^2 which is almost 29% over 1991. However, there is a significant gain in the forest cover in 2014 over 2003. In the treatment region this gain is 82% or 373 km^2, 40% or 376 km^2 in the control region and 36% or 7984 km^2 in the study area. Thus, the net change in forest cover in the entire study area between 1991 and 2014 is a decline of 432 km^2 or 1.4%.

Agricultural area doesn’t change significantly between 1991 and 2003 for the treatment and control regions, as well as the study area. However, between 2003 and 2014, there is a sharp decline. In the treatment region, this decline is reflected as 669 km^2 or 57%. In the comparison region it’s 565 km^2 or 63%, while in the study area, the decline is 11572 km^2 or a decrease of almost one half the area that existed in 2003. Thus the net change in agricultural area in the end year of analysis reflects a sharp decline over the base year.

10.1.1 Spatio- temporal patterns of LULC change

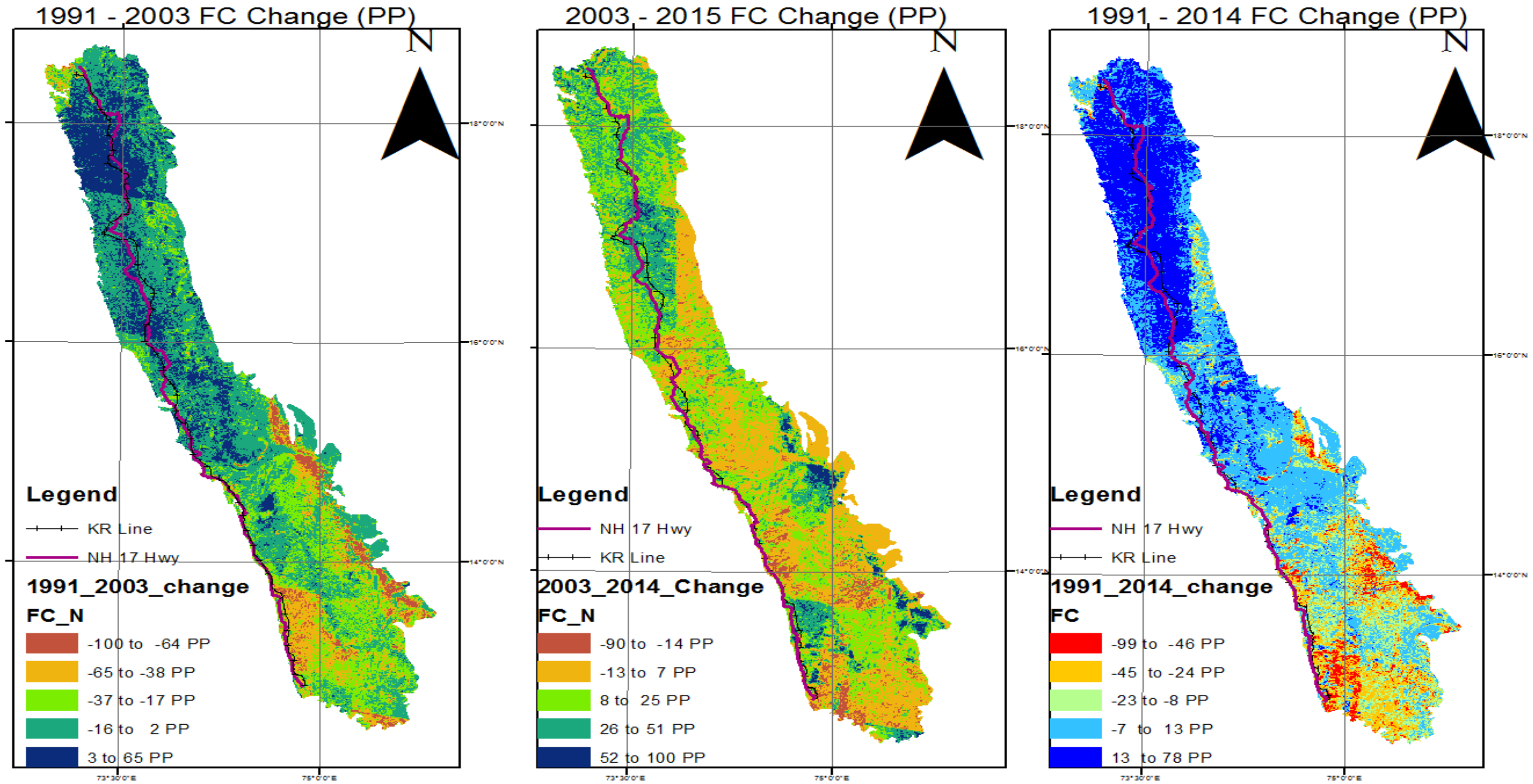
The spatio-temporal patterns of LULC change over the pre-treatment, intermediate and final years were obtained by mapping pixel by pixel changes between the classified data corresponding to each year. The entire area was divided in a grid of 1 km^2 pixels and the percentage LU was extracted for each pixel. The percentage point (PP) change was obtained between the years of analysis. The method is detailed out in the Landuse change report.

The trends in the descriptive tables are spatially reflected in the change maps. Between the years 1991 and 2003, the region around the Konkan Railway line shows a positive trend in forest cover change as seen in **Figure *10.*** In most places this change is in excess of 50 percentage points over the base year. A similar trend is reflected throughout the study area, with the exception of the south-central region, where a negative trend is seen (in excess of -20 percentage points for the most part of this region). Between 2003 and 2014, there is a forest cover decline observed in pockets along the railway line, in the central and southern part. However, in the northern part, there is an increase in the forest cover between 25 and 50 PP in some areas around the railway line , as well as areas far from it. The net spatial distribution of change in forest cover between the years 1991 and 2014 is seen as a positive change around most sections the Konkan Railway line, particularly in the northern part. The area near the tail of the railway shows a decline of 45 to 100 PP. The increase in forest cover along the Konkan Railway line may be attributed to the afforestation activity undertaken by KRCL. In its Annual Report of 2006-2007, KRCL reported that so far it has planted along 5.5 lakh trees (0.55 million) all over the Konkan Railway alignment. In the 2007-08, KRCL reported that it had undertaken plantation of 28.95 lakh samplings of vetveri grass in 85 soil cuttings as a soil erosion control measure.

The spatio-temporal patterns of Open Space LULC are seen in Figure 11*.* Between the base year 1991 and the intermediate year 2003, there is an increase in open spaces near the railway line in the southern part of the study area between 11 to 33 PP. However, there are pockets in the south where there has been a decrease in open space in this time period, by 41 to 100 percentage points. The time period between 2003 and 2014 shows positive change in open spaces in northern part of the study area. In the southern and south central part there is a slight negative change observed in the open spaces but this change Is less than 12 percentage points. In the immediate vicinity of the Konkan Railway line, the change is mainly positive. The overall spatial trend between 1991 and 2014 in open spaces shows a moderate increase around the railway line in the northern half (27 to 48 percentage points) with patches of high positive change (> 35 PP) away from the railway. Certain patches along the eastern edge of the study area show a sharper net increase in open spaces, between 49 and 97 percentage points. However, throughout the study area, the change is between -2 to 9 PP which is slightly positive. There are a few pockets of negative change seen in the extreme south of the study area.

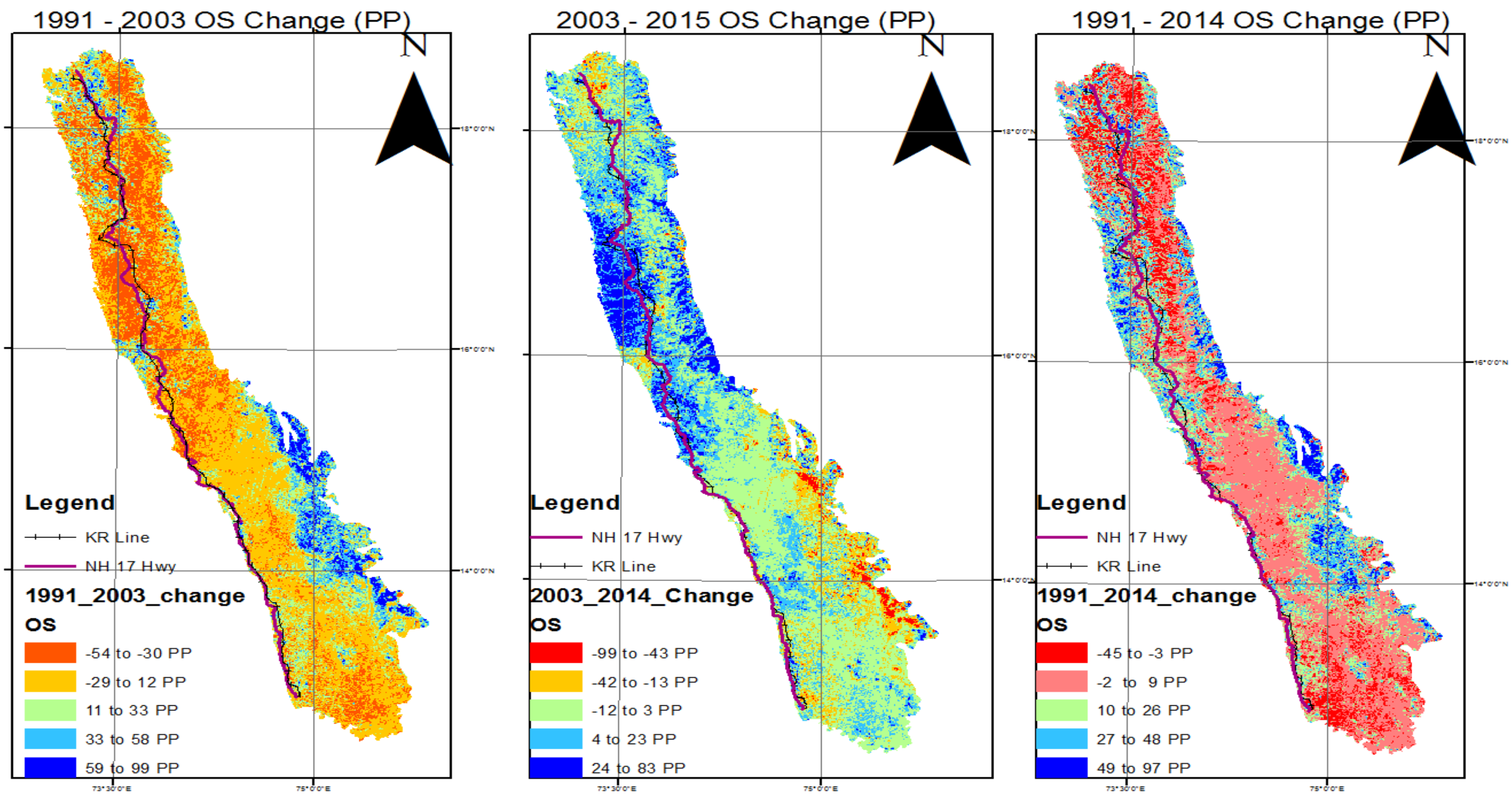
The spatio-temporal patterns of Agricultural LULC are seen in Figure 12. The time period from 1991 – 2003 shows a negative trend in agricultural land in the extreme northern tip in the study area, with either an increase or a negligible agricultural change throughout the region. The southern part of the study area shows a very high change (38 to 94 PP). The regional trends are reflected near the railway line as well. Between 2003 and 2014, there is a decline in the agricultural land around the railway, particularly in the first half of its stretch. The entire northern region of the study area shows a negative trend of 38 to 92 PP. The southern part of the study area shows an overall slight negative change in agricultural land near the railway line, and a moderate decline away from it and a positive trend in the eastern part. The net change in agricultural area between the base and final years is seen spatially along the Konkan Railway line as a negative change in the northern part, between 36 and 97 percentage points. This trend almost mimics the trend between 2003 and 2014 for the northern region. There are certain sections of the line and the study area that do show a lower negative change in agricultural land in the south central region. In the south-central regions of the study area, the change is to the lower side of negative change (8 to -19 percentage points). The southern tip of the study area shows a more positive change (31 to 93 PP).

Figure 10: Spatial Temporal Change in Forest Cover



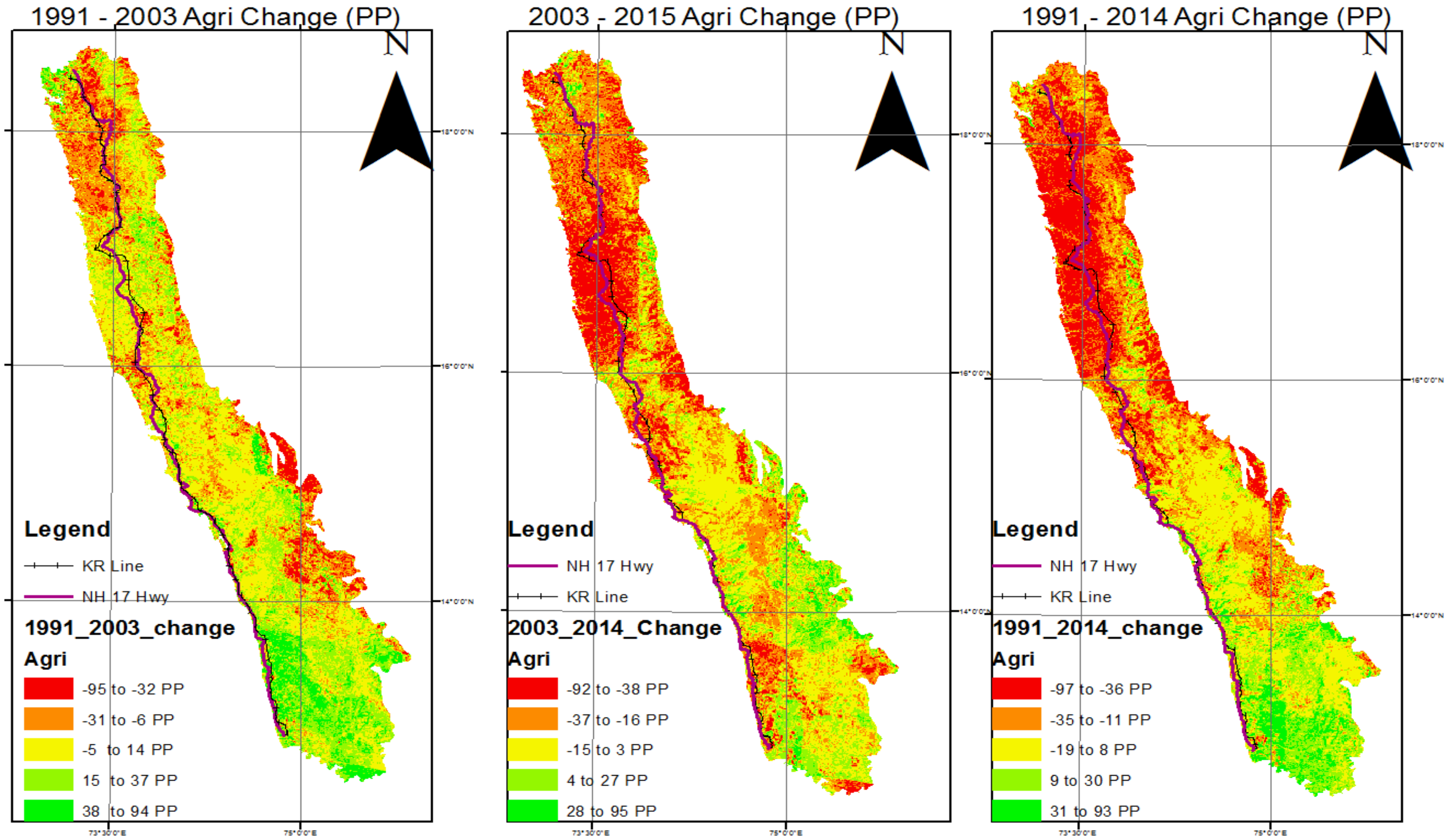
Source: The map is generated by processing multi-temporal and multi-spectral satellite data procured from USGS and NRSC

Figure 11: Spatial Temporal Change Open Space



Source: The map is generated by processing multi-temporal and multi-spectral satellite data procured from USGS and NRSC

Figure 12: Spatial temporal change in agricultural land



Source: The map is generated by processing multi-temporal and multi-spectral satellite data procured from USGS and NRSC

10.2 DID results from LULC analysis

The DID results are obtained for LULC when the treatment area is 2 km on either side of the railway line and control area is 2km on either side of the virtual line that is 10km away from the railway line and parallel to it. The summary results are as follows:

Table 11:Summary results: Land use Change using Satellite Images

Land use Change using Landsat data (1991-2015) and LISS3 data (1991-2014)				
	Open Space	Forest Cover	Water Body	Total Agricultural Land
DID	0.095***	-0.025	0.004	-0.072**
	(0.019)	(0.035)	(0.007)	(0.028)
Observations	600	600	600	600
R-squared	0.265	0.177	0.021	0.328
Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 The estimations results ae based on standard DID equation as set out in Section 6.7.3				

As per the results the Open Space LULC type shows a significant increase in the post-treatment period. The open space has increased by 9.5 percentage points for treated area between 1991-2014. Similarly, the agricultural area showed a decline in the treatment region of 7.2 percentage points. This is also similar to trend we observe for cultivated land between 1991-2011 from the census data. The results are insignificant for forest cover and water body. The forest cover in the census data too shows no significant change in close proximity to the railway station.

10.3 Hotspot analysis results

The hotspot area land cover between Mayem and Bali in Goa were extracted using the classified outputs for the given years. In the hotspot area, the open space decreases by 2116 Ha between 1991 and 2003 and increases by 19539 Ha between 2003 and 2014. Thus, the net change in open space between 1991 and 2014 is a positive 17423 Ha. Water Body LULC type shows a decrease of 959 Ha between 1991 and 2003. While it shows a further decrease of 95 Ha between 2003 and 2014. The net change in water body is a decrease 1054 Ha. Forest cover shows a decrease of 3929 Ha between 1991 and 2003. While it shows an increase of 13486.2 Ha between 2003 and 2014. The net change in forest cover between 1991 and 2014 for the hotspot area is a positive 9557 Ha. Agricultural land increases between 1991 and 2003 by 6687 Ha. It decreases by 33832 Ha between 2003 and 2014. The net change in agricultural area between 1991 and 2014 is a negative 27145 Ha.

Table 12: Temporal change in LULC for the hotspot region.

LU Type (Area in Hectares)/Year	1991	2003	2014
Open Space	7133.4	5017	24556.3
Water Body	5928.5	4969.4	4874.4
Forest Cover	43785.4	39856.2	53342.4
Agricultural Land	41908.8	48595.9	14763.9

These results are important in the light of the concerns expressed by environmentalist's pertaining to degraded forest cover, loss of water bodies and impact on agriculture in the hotspot area, when the Konkan Railway was proposed. The increase in area of forest cover and an insignificant decrease in water bodies is contrary to the predictions of the environmentalists. The decline in agriculture on the other hand, is a feature across the state of Goa due to declining profits in agriculture, high wage rates for agricultural labour and shift towards non-farm activities.

11. Conclusion and policy implications

In this section, we attempt to 'merge' the qualitative and quantitative findings from the various steps we carried out, in order to advance one set of policy recommendations. The Indian government successively commissioned and released two reports by different expert panels for making recommendations for the conservation, protection and rejuvenation of the Western Ghats region through which the Konkan Railway passes. The two reports while recommending restrictions on large-scale projects like dams, power plants, roads and railways in certain sections of the ecologically sensitive zones in the Western Ghats, provide hardly any empirical evidence for the long-term socioeconomic and environmental costs and benefits of the large infrastructure projects already operating in the region.

The dearth of empirical literature on large infrastructure projects is also a much wider phenomenon. Large infrastructure projects are frequently criticised for being characterized by cost overruns, time delays and public resistance. The current literature on controversial large infrastructure projects is dominated by works which address issues of environmental destruction, displacement and loss of livelihoods. The literature emanating from 'environmental justice' or 'environmentalism of the poor' scholarship has been especially critical of such projects, viewing them as inherently incompatible with sustainability (Lehtonen 2019). This notion has also been largely accepted in policy recommendations for preservation of Western Ghats. Though contested projects continue to be referred in subsequent debates about environmental impacts., they are rarely systematically studied later for their long-term impact. The importance of doing so cannot be emphasized enough for planning for development and environment of a region. In the absence of such detailed long-term assessments of various large infrastructure projects, stakeholders are left with no empirical evidence on which to base their decisions regarding future developmental activities in the Western Ghats or more widely in developing countries. Our impact evaluation of one of the largest and controversial infrastructure project in the Western Ghats is an attempt towards providing empirical evidence and exploring causal mechanisms of the performance of a real-world infrastructure project.

A defining feature of the historical development experience of the region traversed by the Konkan Railway is the high level of male outmigration for better economic opportunities. The region's migratory links with Mumbai, goes as far back as the 19th century in certain instances. The early migrants travelled by steamships, which remained a competitive mode of transport till early 20th century. After the stoppage of steamer services in 1980's, road was the only means of long distance transport for most of the region. The Konkan Railway therefore forms a part of a much longer history of labour mobility in this region. Given this historical experience, the Konkan Railway has played an important role in improving the connectivity between Mumbai and Mangalore, the stations at either end of the Konkan Railway system. By cutting down the distance and travel time, and by providing a cheap and safe means of transport, it has improved the overall accessibility to and from the region and has also improved connectivity within the region. It has amplified the already existing pattern of travel in the region, most importantly to Mumbai. At the same time, it has enhanced the available choice of destinations by connecting the region to the rest of country, namely Gujarat, New Delhi, and Kerala.

The Konkan Railway has emerged as the preferred mode of transport as compared to the highway due to two major factors. Firstly, the subsidized train fare and lack of seasonal fluctuation in fare makes it more affordable than bus transport. The railways in India have been playing the role of meeting the transportation needs of the economically disadvantaged sections of the society, by keeping train fares low. In India therefore, public policy, plays a significant role in shaping people's choice for rail as the preferred mode of transport. Secondly, over and above the monetary factor, for the travellers the railway provides a tangibly different experience in terms of comfort, on board-facilities and safety which buses or an expanded highway network may not be able to match.

While several measures have been taken to maximize the explanatory power of this quasi-experimental study, two caveats shall not remain unmentioned: first, the Konkan region is also crossed by a national highway that has been built before the Konkan Railway. We controlled for the distance to this highway in our study, but a clear isolation of the individual effects may remain elusive, also because of interactions between the two infrastructures. Second, as noted in our Theory of Change, distributional effects and spillovers may have taken place – in the context of our evaluation, such interactions between treatment and comparison units may particularly be an issue. For example, observed effects on population may partly be driven by migration from areas falling in the comparison group to areas falling in the treatment group. However, to what extent the first of these caveats should be considered a shortcoming of the study is open to debate. In the real-world scenario of infrastructure interventions (Hansen et al. 2011) suggest to pay due attention to "mediation mechanisms when the project has purposeful selection" (Hansen et al. 2011: 7), which in our case implies determining how the railway and the highway can be made to work in more complementary ways. Instead of working as a linear mode of transport from station to station, the railway and the highway could be made to work in a manner that it forms an integrated transport system for travel within and outside the region, by measures such as having more buses ferrying passengers to and fro the station, a common ticketing system and with schedules which match the train timings. This can help the railways to penetrate deeper into the districts and neighbouring districts.

The patronage from passengers is in stark contrast with the performance of freight. Despite, the considerable savings in distance and travel time offered by the Konkan Railway, the freight traffic fell short of the traffic projections. Moreover, contrary to the initial expectations that the project will usher in an era of industrial development in the project influence area and change the migration-prone character of the economy by creating job opportunities our interaction with the key informants suggest that the Konkan Railway has not contributed much to industrial development. Another important conclusion from the exercise was that the establishment of a new transport infrastructure is by itself unlikely to generate new industrial investments, especially in lagging regions (Chakravorty 2003). An important lesson can be drawn from this finding that railways can lead to industrial development and consequently generate freight for itself, under the following non-exhaustive list of conditions: the state governments in providing a proper climate for industrial investment; investors take advantage of the railway line; public participation in decision making for setting up industries to manage public resistance and delays and suitable accompanying infrastructure such as ports. On the one hand, without these conditions being fulfilled, generating freight to meet the actual projections is unlikely. On the other hand, even with these conditions being fulfilled increased freight is likely but not certain. Transport infrastructure may therefore be a necessary but not sufficient condition for changing the geography of industrial location.

There were several key learnings from the analysis of the operating performance of Konkan Railway. Firstly, it is intrinsic to the nature of infrastructure projects that by sinking present resources in exchange for future benefits, they are affected by uncertainty and risks. In the case of Konkan Railway, the traffic projection study carried out by RITES does not appear (based on the available documentation) to have accounted for risks and/or uncertainties, leading to overestimation of likely emergence of freight traffic. It also illustrates the uncertainties in the benefits to be derived from infrastructure projects when the factors external to the operation of the project play a key role in determining its viability. Importantly, since the demand for transport is an outcome of derived demand, that is, demand for transport occurs as a result of demand from other sectors. In the case of the Konkan Railway, the regulatory uncertainties, changing macro-economic conditions and consequent the fall in output of several industrial units, affected the demand for freight services. However, it is also true that in the case of the Konkan Railway, the projections themselves seem to have been excessively optimistic. The findings from the study highlights the importance of paying closer attention to better forecasting and the implementation and regular updating of risk analysis for infrastructure projects (Ramjerdi and Fearnley 2014).

Even then, the detailed analysis carried out establishes the point that despite falling short of projections, there are nevertheless significant benefits that have been derived as direct benefits, from the construction and operation of the Konkan Railway. We found that the Konkan Railway had a positive effect on population sizes in the villages and towns in the proximity of railway stations and on the female/male ratio. It seems plausible to conclude from this that the railway access has reinforced the pre-existing pattern of high levels of male migration. The improved accessibility makes it easier to function from more than one home and also helps in maintaining social links with the place of origin. By providing a cheap, and comfortable means of transport it has encouraged people to make more frequent trips for business, religious and familial reasons.

The decline in main workers and the changes in the occupational categories of main workers, further led to the possible conclusion that the Konkan Railway has encouraged diversification of economic activities and of workplaces by making it easier to access employment opportunities via daily commutes between rural and urban areas. The socioeconomic and employment profile of the seasonal and commuting workers, are an interesting subject of further research. Increase in other workers, that is those employed in non-agricultural activities led to the possible conclusion that the Konkan Railway has given a considerable push in terms of new economic activities, even though such analyses could only remain preliminary. Deeper analyses of economic survey data may shed more light on supply-side aspects of outcomes regarding the labour market and economic activities. There also seems to be a large number of short distance travellers and daily commuters who use the Konkan Railway for more local travel. A more thorough study of the local patterns of travel might reveal useful insights on how to use the Konkan Railway as a local modes of transport that penetrates deeper into the regions surrounding it.

As far as the land use change is concerned, the forest cover results from the census data captured village wise land use changes and the results showed that there was no significant change in forest cover for villages within 10km of the station as compared to villages more than 10kms away for the time-period 1991-2011. The satellite data captured land use changes along 2 km on either side of the railway line, which in the case of linear infrastructure such as the railway, is important to consider, as establishment and maintenance of railway lines cause direct loss of vegetation cover on either side on the line.. During the time of its construction, environmentalists had also argued that the railway would generally be detrimental to ecosystem and ecological balance of the region. The descriptive statistics from the satellite data classification show that forest cover decreased between 1991-2003, during the period of construction and partial operation of the Konkan Railway. However, it has increased along the railway line between 1991-2014. The increase in forest cover along the Konkan Railway line may be plausibly attributed to the afforestation activity undertaken by KRCL. The analysis could hence not substantiate the concerns raised during the time of the construction of the Konkan Railway about the environmental degradation it might bring in its wake, at least not at a larger scale

There are several other important policy implications of the findings from the study. Developing countries still face a large transport infrastructure gap. The transport investments they make today will lock in development patterns for decades to come and will have a direct bearing on sustainable development. While, the literature from the fields of economic geography, migration, and labour economics acknowledges the role played by transport in labour mobility, this study is among the few that helps in quantifying the changes in population and workforce composition in response to an improved transport infrastructure. This has important implications as far as investment in transport is concerned. The impact evaluation raises pertinent questions such as the implications of improved transport network for migration – whether long-term or seasonal – and for daily commuting to work from rural to urban areas. By incorporating the perspective that migration is used as a livelihood diversification and income enhancing strategy by households and commuting as a strategy for diversification of workplace, our study allows to derive some conclusions related to labour market outcomes and regional employment and development. For development planners and policy makers, the study encourages considering the impact of transport infrastructure on geographic labour mobility and labour market outcomes in the sending and receiving regions. While planning investment, it encourages transport and development planners in both sending and receiving regions to take into consideration how transport infrastructure helps in diversification of workplace and economic activities. Another important area of further research is whether improved transport connectivity encourages people to undertake rural-urban daily rather than migrate. The findings from this study can help transport ministries and urban planners to better understand its role in present developing country circumstances and allow them to make more informed decisions regarding policy and investment in railways.

Appendixes

Appendix A: Key informant interview Semi-Structured Interview Questionnaire

Goa Activists, political figures who participated in the debate around the Konkan Railway alignment in the 1990's

- What was your position with regards to the Konkan Railway when it was proposed?
- What was your position regarding the economic impact of the Konkan Railway?
- What was your position regarding its social impact?
- What was your position regarding its environmental impact?
- What do you think are the major benefits of Konkan railways? What do you think has been the negative impact of Konkan Railway?
- Do you think Konkan Railway has improved employment and education opportunities? How?
- Do you think Konkan Railway has brought about industrial development in the region? How?
- Do you think it has increased or decreased migration?
- Has it had any impact on tourism?
- What do you think has been the impact of Konkan Railway on the local environment?

Local self-government bodies

- Can you give us a brief introduction of the village and its economic profile regarding the primary occupation of the people?
- What mode of transportation is generally used by the people for long distance transport?
- What are the places mostly frequented by the villagers?
- Which is the most used railway station?
- How do you go to the railway station? What is the cost of getting to the station?
- How do you go to the bus station? What is the cost of getting to the bus station?
- What do you think are the major benefits of Konkan railways? What do you think has been the negative impact of Konkan Railway?
- Do you think Konkan Railway has improved employment and education opportunities? How?
- Do you think Konkan Railway has brought about industrial development in the region? How?
- Has it had any impact on tourism?
- Do you think it has increased or decreased migration to/from the village?
- What do you think has been the impact of Konkan Railway on the local environment?

Industry/Trade persons

- Could you give us a brief overview of the company and its operations? Briefly describe your role?
- What are the goods produced in the industry? From where do you procure your raw materials?
- What is the main and the secondary mode of transportation used for freight movement? Can you elaborate the reasons for choosing them?
- Has there been a shift in the mode of transport used in the last five years? Rail relative to other modes? Reasons why?
- Is rail a competitive mode of transport for the company on the basis of volume/distance/cost/ service frequency?
- What are the major economic, regulatory and environmental challenges in operation faced by the company?

KRCL officials

- Can you briefly describe the general freight passenger traffic experienced by the Konkan Railway in Goa?
- Who are the users of the freight movement along the Goa Konkan Railway route?
- What are the challenges faced in increasing the freight carried?
- What do you think are the major barriers to the changing freight mode to rail?
- What do you think is the impact of the Konkan Railway on the environment?
- Is there a proposition to double the Konkan Railway tracks?
- What do you think are the benefits of the Konkan Railway?
- Do you think Konkan Railway has improved employment and education opportunities? How?
- Has it had any impact on tourism?
- Do you think it has increased or decreased migration to and from Goa?
- Do you think Konkan Railway has brought about industrial development in the region? How?
- What are the economic, environmental and regulatory challenges faced by this division in the operation of Konkan Railway?

Appendix B: Outcome Variables and definitions

Table B1: Census outcome variables

Outcome	Outcome Variable Definition	Availability
Workforce Composition	$Crude\ Workforce\ Participation\ Rate = \frac{Total\ Workers}{Total\ Population} * 100$	Rural Urban
	$Main\ Workers = \frac{Total\ Main\ Workers}{Total\ Workers} * 100$	Rural Urban
	$Cultivators = \frac{Main\ Cultivators}{Total\ Main\ Workers} * 100$	Rural Urban
	$Main\ Agricultural\ Labour = \frac{Main\ Agricultural\ Labour}{Total\ Main\ Workers} * 100$	Rural Urban
	$Main\ Household\ Industry\ Workers = \frac{Main\ Household\ Industry\ Workers}{Total\ Main\ Workers} * 100$	Rural Urban
	$Main\ Other\ Workers = \frac{Main\ Other\ Workers}{TotaL\ Main\ Workers} * 100$	Rural Urban
Population Composition	$Population$	Rural Urban
	$Rural\ Population$	Rural
	Urban Population	Urban
	Sex Ratio= $\frac{No.of\ females}{No.of\ Males} * 1000$	Rural Urban
Land Use	$Forest\ Land = Forest\ Land\ in\ hectares$	Rural
	$Cultivated\ Area = Total\ Irrigated\ Area + Total\ Unirrigated\ Area\ (in\ hectares)$	Rural
	$Area\ not\ under\ agricultural\ uses\ in\ heactres$	Rural
	$Culturable\ Waste\ Area\ in\ Hectares$	Rural

Main Workers: Those workers who had worked for the major part of the reference period (i.e. 6 months or more) are termed as Main Workers.

Marginal Workers: Those workers who had not worked for the major part of the reference period (i.e. less than 6 months) are termed as Marginal Workers.

Cultivator: For purposes of the census a person is classified as cultivator if he or she is engaged in cultivation of land owned or held from government or held from private persons or institutions for payment in money, kind or share. Cultivation includes effective supervision or direction in cultivation. A person who has given out her/his land to another person or persons or institution(s) for cultivation for money, kind or share of crop and who does not even supervise or direct cultivation of land, is not treated as cultivator. Similarly, a person working on another person's land for wages in cash or kind or a combination of both (agricultural labourer) is not treated as cultivator.

Agricultural Labourers: A person who works on another person's land for wages in money or kind or share is regarded as an agricultural labourer. She or he has no risk in the cultivation, but merely works on another person's land for wages. An agricultural labourer has no right of lease or contract on land on which she/he works.

Household Industry Workers: Household Industry is defined as an industry conducted by one or more members of the household at home or within the village in rural areas and only within the precincts of the house where the household lives in urban areas. The larger proportion of workers in the household industry consists of members of the household. The industry is not run on the scale of a registered factory which would qualify or has to be registered under the Indian Factories Act. Some of the typical industries that can be conducted on a household industry basis are: Foodstuffs : such as production of floor, milking or dehusking of paddy, grinding of herbs, production of pickles, preservation of meat etc. Beverages: such as manufacture of country liquor, ice cream, soda water etc., Tobacco Products: such as bidi, cigars, Textile cotton, Jute, Wool or Silk, Manufacture of Wood and Wood Products, Paper and Paper Products etc.

Other Workers: All workers, i.e., those who have been engaged in some economic activity during the last one year, but are not cultivators or agricultural labourers or in Household Industry, are 'Other Workers(OW)'. The type of workers that come under this category of 'OW' include all government servants, municipal employees, teachers, factory workers, plantation workers, those engaged in trade, commerce, business, transport banking, mining, construction, political or social work, priests, entertainment artists, etc.

Non-Workers: A person who did not at all work during the reference period was treated as non-worker. The non-workers broadly constitute Students who did not participate in any economic activity paid or unpaid, dependant such as infants or very elderly people not included in the category of worker, pensioners, beggars, vagrants, prostitutes and persons having unidentified source of income and with unspecified sources of subsistence and not engaged in any economically productive work during the reference period. Others, this category includes all Non-workers who may not come under the above categories such as rentiers, persons living on remittances, agricultural or non-agricultural royalty, convicts in jails or inmates of penal, mental or charitable institutions doing no paid or unpaid work and persons who are seeking/ available for work.

Forest Area: This includes all land classified either as forest under any legal enactment, or administered as forest, whether State owned or private, and whether wooded or maintained as potential forest land. The area of crops raised in the forest and grazing lands or areas open for grazing within the forests remain included under the “forest area”.

Area under Non-agricultural Uses: This includes all land occupied by buildings, roads and railways or under water, e.g. rivers and canals, and other land put to uses other than agriculture.

Culturable Waste Land: This includes land available for cultivation, whether taken up or not taken up for cultivation once, but not cultivated during the last five years or more in succession including the current year for some reason or the other. Such land may be either fallow or covered with shrubs and jungles, which are not put to any use. They may be accessible or inaccessible and may lie in isolated blocks or within cultivated holdings

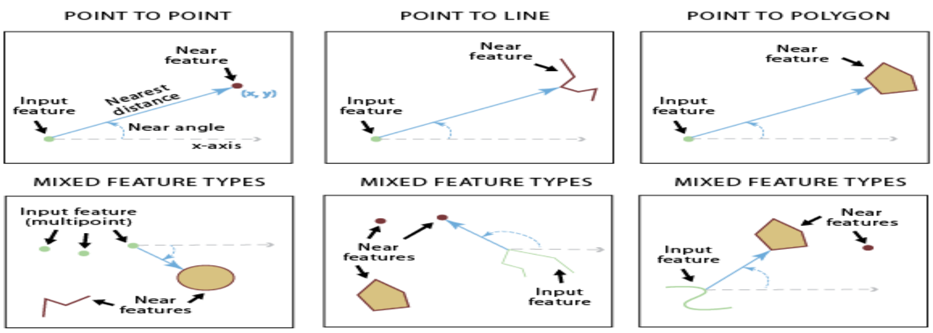
Cultivable Area: It is the sum of irrigated area and unirrigated area. The area is assumed to be irrigated for cultivation through such sources as canals (Govt. and Private), tanks, tube -wells, other wells and other sources.

Appendix C

GIS Technique for generating distance from coast, highway and elevation

The digitized village boundaries for Maharashtra and Goa were purchased from a professional GIS consultancy, ML InfoMap Ltd. These boundaries are based on the 2011 village census maps. The Karnataka village boundaries were procured from Karnataka Remote Sensing Applications Centre (KSRAC) and are based on 2001 village census maps. All the vector data was procured in the shapefile format that can be loaded in ArcGIS version 10.5. The shapefile layers, containing the study area boundary layer, the village boundaries for the three states, the railway line, the Konkan Railway station layer and the NH17 highway, were standardised to the projection of the Universal Transverse Mercator (UTM) zone 43N, a standard projection system used for the region. The geometry attributes of the villages were then obtained, including the area within the boundary, the location of the centroids of the village polygons, and the X and Y co-ordinates of these centroids. The euclidean distances from the coast, the KR line and the highway were populated in the village centroid's attribute table using proximity analysis tools in ArcGIS. Figure C 1 illustrates how the 'Near Analysis' tool in ArcGIS can be used to obtain distances between multiple feature datasets.

Figure C1: Near analysis between multiple sets of features



Source: ArcGIS reference manual

The 1991, 2001 and 2011 census datasets were then joined to the spatial attribute data in GIS based on the 2011 unique census identifier. In order to obtain elevations, Digital Elevation Models (DEM) of 30m spatial resolution of the Cartosat-1 satellite were downloaded from the National Remote Sensing Centre's (NRSC) web portal, Bhuvan. The datum (reference of an ellipsoid that best approximates the shape of the earth by considering the irregular surface for a given area) of the DEM was then changed to the Earth Gravitational Model, EGM 96 from the standard World Geodetic System, WGS 84 in Erdas Imagine. The EGM 1996 model is used to calculate the height offset between the WGS84 ellipsoidal height and the Mean Sea Level (MSL) on any place on the globe. The default values populated in the DEM are in terms of this offset distance. Thus, the elevation values in the DEM rasters were recalculated to show the true elevations from the mean sea level by changing the datum. The values of the elevations obtained in DEM were checked against the elevations of the corresponding locations in Google Earth. The mean error obtained was -1.1 m for a set of 30 observations. The images were mosaiced and imported in the ArcGIS software and the elevations at the centroids of the village shape boundaries were obtained using a spatial analyst tool that extracts the value of the elevation from the raster in to the point feature based on its co-ordinates.

Appendix D

Accuracy Assessment Reports and Kappa Values.

The post classification accuracy assessment was done using stratified random sampling using the LULC classes for 500 points for year 1991 and 2014 and 200 points across the study area with respect to the reference data.

Definitions:

Producers Accuracy: Producers Accuracy is the accuracy of the of the reference points with respect to the training samples collected. Producers accuracy helps understand the omission error.

Users Accuracy: Users Accuracy is the accuracy of the reference points in the classified with respect to the reference data.

Kappa Values: Kappa statistics tells us the extent to which the classified data is in agreement to actual ground values or reference data as compared to a complete chance agreement. Hence, kappa value of 0.60 for a certain LULC class means that the classified data agrees with reference data by over 60% as compared to what it would have agreed by chance.

Thus, K = (observed accuracy – chance agreement)/ (1 – chance agreement).

Table D1: Accuracy assessment report and kappa values for hybrid classification for the year 1991

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Kappa
Open Spaces	113	66	62	54.87%	93.94%	0.9217
Agricultural Land (Uncropped)	51	77	45	88.24%	58.44%	0.5193
Water Body	11	11	11	100.00%	100.00%	1
Forest Cover	270	253	246	91.11%	97.23%	0.9399
Agricultural Land (cropped)	90	143	86	95.56%	60.14 %	0.2715
Totals	500	500	413			
Overall Classification Accuracy = 82.60%						**Overall Kappa Statistics = 0.7295**

Table D2: Accuracy assessment report and kappa values for hybrid classification for the year 2003.

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Kappa
Water Body	23	22	20	86.96%	90.91%	0.8973
Forest Cover	82	57	55	67.07%	96.49%	0.9405
Open Space	50	43	31	62.00%	72.09%	0.6279
Agricultural land (cropped+uncropped)	44	78	38	86.36 %	48.71%	0.4239
Totals	199	200	144			
Overall Classification Accuracy = 72%						**Overall Kappa Statistics = 0.7224 (excluding cloud data)**

Table D3: Accuracy assessment report and kappa values for hybrid classification for the year 2014

Class Name	Reference Totals	Classified Totals	Correct	Producers Accuracy	Users Accuracy	Kappa
Open Space	146	121	87	59.59%	71.90%	0.6025
Agricultural Land (uncropped)	39	29	14	35.90%	48.28%	0.4388
Water Body	8	12	8	100.00%	66.67%	0.6612
Forest Cover	246	247	216	87.80%	87.45%	0.7520
Agricultural land Cropped)	47	61	31	65.96%	50.82%	0.4569
Totals	497	498	367			
Overall Classification Accuracy = 73.69%						**Overall Kappa Statistics = 0.6050**

Online Appendixes

Online appendix A: Binary Treatment main analysis, robustness check, categorical treatment results 1991-2011

https://www.3ieimpact.org/sites/default/files/2020-03/DPW1.1050-Online-appendix-A-Binary-treatment-main-analysis-2011.pdf

Online appendix B: Results for Continuous treatment and additional Heterogeneity Analysis 1991-2011

https://www.3ieimpact.org/sites/default/files/2020-03/DPW1.1050-Online-appendix-B-Heterogenity-additional-hetero.pdf

Online appendix C: Estimation Results for time period 1991-2001

https://www.3ieimpact.org/sites/default/files/2020-03/DPW1.1050-Online-appendix-C-Estimation-Results-2001.pdf

Online appendix D: Detailed LULC Report

https://www.3ieimpact.org/sites/default/files/2020-03/DPW1.1050-Online-appendix-D-LULC-change-analysis.pdf

References

Abadie, A, Athey, S, Imbens, GW & Wooldridge, J. 2017. *When should you adjust standard errors for clustering?* National Bureau of Economic Research.

Alvares, C. 2002. *Fish Curry and Rice*. Goa: The Other India Press.

Anderson, JR, Hardy, EE, Roach, JT & Witmer, RE. 1976. *A land use and land cover classification system for use with remote sensor data*. V. 964. (Professional Paper 964). US Government Printing Office.

Andrés, L, Biller, D & Herrera Dappe, M. 2013. *Reducing poverty by closing South Asia's infrastructure gap*. Washington DC: World Bank. Available from: https://openknowledge.worldbank.org/handle/10986/17847.

Astbury, B & Leeuw, FL. 2010. Unpacking Black Boxes: Mechanisms and Theory Building in Evaluation. *American Journal of Evaluation*. 31(3):363–381. doi.org/10.1177/1098214010371972.

Atack, J, Bateman, F, Haines, M & Margo, RA. 2010. Did railroads induce or follow economic growth? *Social Science History*. 34(2):171–197.

Atack, J, Haines, M & Margo, RA. 2011. Railroads and the Rise of the Factory: Evidence for the United States, 1850-1870. In: *Economic evolution and revolution in historical time*. P. Rhode, J. Rosenbloom, & D. Weiman, Eds. Stanford University Press.

Bah, M, CissÈ, S, Diyamett, B, Diallo, G, Lerise, F, Okali, D, Okpara, E, Olawoye, J, et al. 2003. Changing rural–urban linkages in Mali, Nigeria and Tanzania. *Environment and Urbanization*. 15(1):13–24. doi.org/10.1177/095624780301500104.

Baker, J. 1995. Survival and accumulation strategies at the rural-urban interface in north-west Tanzania. *Environment and urbanization*. 7(1):117–132.

Banerjee, A, Duflo, E & Qian, N. 2012. *On the road: Access to transportation infrastructure and economic growth in China*. (17897). National Bureau of Economic Research.

Bansal, V, Yoshifumi, U & Rawal, V. 2018. *Agricultural Tenancy in Contemporary India: An Analytical Report and A Compendium of Statistical Tables based on NSSO Surveys of Land and Livestock Holdings*. (Monograph 18/1). New Delhi: Society for Social and Economic Research. Available from: http://www.networkideas.org/featured-articles/2018/05/agricultural-tenancy-in-contemporary-india/ [Accessed 1 September 2018].

Baum-Snow, N, Brandt, L, Henderson, JV, Turner, MA & Zhang, Q. 2017. Roads, Railroads, and Decentralization of Chinese Cities. *The Review of Economics and Statistics*. 99(3):435–448. doi.org/10.1162/REST_a_00660.

Bertrand, M, Duflo, E & Mullainathan, S. 2004. How Much Should We Trust Differences-In-Differences Estimates?*. *The Quarterly Journal of Economics*. 119(1):249–275. doi.org/10.1162/003355304772839588.

Bhuyan, PJ. 2016. Mumbai-Goa highway sees over 1,000 deaths a year. *Hindustan Times*. 16 May. Available from: http://www.hindustantimes.com/mumbai/mumbai-goa-highway-sees-over-1-000-accidents-a-year/story-zsCB4boPS1VdyfBRAD5I5J.html [Accessed 29 November 2017].

Broegaard, E, Freeman, T & Schwensen, C. 2011. Experience from a phased mixed-methods approach to impact evaluation of Danida support to rural transport infrastructure in Nicaragua. *Journal of Development Effectiveness*. 3(1):9–27. doi.org/10.1080/19439342.2010.545893.

Burley, TM. 1961. Land Use or Land Utilization? *The Professional Geographer*. 13(6):18–20. doi.org/10.1111/j.0033-0124.1961.136_18.x.

Carvalho, S & White, H. 1997. *Combining the quantitative and qualitative approaches to poverty measurement and analysis: the practice and the potential*. (World Bank Technical Paper No.366.). Washington, DC: The World Bank.

Chakravorty, S. 2003. Industrial location in post-reform India: patterns of inter-regional divergence and intra-regional convergence. *Journal of Development Studies*. 40(2):120–152. doi.org/10.1080/00220380412331293797.

Chandra, A & Thompson, E. 2000. Does public infrastructure affect economic activity?: Evidence from the rural interstate highway system. *Regional Science and Urban Economics*. 30(4):457–490.

Chen, AZ, Fischer, J, Fraker, A, Shah, NB, Shirrell, S & Stein, D. 2017. Welfare impacts of an entry-level solar home system in Uganda. *Journal of Development Effectiveness*. 9(2):277–294. doi.org/10.1080/19439342.2017.1307248.

Claveau, F. 2011. Evidential variety as a source of credibility for causal inference: beyond sharp designs and structural models. *Journal of Economic Methodology*. 18(3):233–253. doi.org/10.1080/1350178X.2011.611025.

Clawson, M & Stewart, CL. 1965. Land use information. A critical survey of US statistics including possibilities for greater uniformity. In: *Land use information. A critical survey of US statistics including possibilities for greater uniformity.* Baltimore: Johns Hopkins Press.

Datta, S. 2012. The impact of improved highways on Indian firms. *Journal of Development Economics*. 99(1):46–57.

Deshingkar, P. 2010. Migration, remote rural areas and chronic poverty in India. *Overseas Development Institute (ODI) Working Paper*. 323.

Deshingkar, P & Grimm, S. 2005. *Internal migration and development: a global perspective*. United Nations Publications.

Deshingkar, P, Rao, SL, Akter, S & Farrington, J. 2009. The evolving pattern of circular migration and commuting: household surveys in Andhra Pradesh. *Circular migration and multilocational livelihood strategies in rural India*. 58–87.

Donaldson, D. 2010. *Railroads of the Raj: Estimating the Impact of Transportation Infrastructure*. (w16487). Cambridge, MA: National Bureau of Economic Research. doi.org/10.3386/w16487.

Donaldson, D & Hornbeck, R. 2016. Railroads and American economic growth: A “market access” approach. *The Quarterly Journal of Economics*. 131(2):799–858.

Duflo, E & Pande, R. 2007. Dams. *The Quarterly Journal of Economics*. 122(2):601–646.

Estache, A. 2010. A survey of impact evaluations of infrastructure projects, programs and policies. *European Centre for Advanced Research in Economics (ECARES) Working Paper*. 5:2010.

Faber, B. 2014. Trade integration, market size, and industrialization: evidence from China’s National Trunk Highway System. *The Review of Economic Studies*. 81(3):1046–1070.

Fafchamps, M & Shilpi, F. 2003. The spatial division of labour in Nepal. *Journal of Development Studies*. 39(6):23–66. doi.org/10.1080/00220380312331293577.

Favereau, J. 2016. On the analogy between field experiments in economics and clinical trials in medicine. *Journal of Economic Methodology*. 23(2):203–222. doi.org/10.1080/1350178X.2016.1157202.

Fishlow, A. 1965. *American Railroads and the Transformation of the Ante-bellum Economy*. V. 127. Harvard University Press Cambridge, MA.

Fishlow, A & Fogel, RW. 1971. Quantitative Economic History: An Interim Evaluation Past Trends and Present Tendencies. *The Journal of Economic History*. 31(1):15–42.

Gadgil, M, Krishnan, B, Vijayan, V, Borges, R, Sukumar, R & Subrahmanyam, G. 2011. *Report of the Western Ghats ecology expert panel: Part 1*. Ministry of environment and forests ,Government of India. Available from: http://www.moef.nic.in/downloads/public-information/wg-23052012.pdf.

Ghani, E, Goswami, AG & Kerr, WR. 2016. Highway to success: The impact of the Golden Quadrilateral project for the location and performance of Indian manufacturing. *The Economic Journal*. 126(591):317–357.

Handy, S. 2005. Smart Growth and the Transportation-Land Use Connection: What Does the Research Tell Us? *International Regional Science Review*. 28(2):146–167. doi.org/10.1177/0160017604273626.

Hansen, H, Andersen, OW & White, H. 2011. Impact evaluation of infrastructure interventions. *Journal of Development Effectiveness*. 3(1):1–8. doi.org/10.1080/19439342.2011.547659.

Hidrobo, M, Peterman, A & Heise, L. 2016. The Effect of Cash, Vouchers, and Food Transfers on Intimate Partner Violence: Evidence from a Randomized Experiment in Northern Ecuador. *American Economic Journal: Applied Economics*. 8(3):284–303. doi.org/10.1257/app.20150048.

Hiran, U. 2017. Migrants dominate workforce in marine fisheries sector. *The Hindu* (Kochi). 12 June. Available from: https://www.thehindu.com/news/cities/Kochi/migrants-dominate-workforce-in-marine-fisheries-sector/article18964456.ece [Accessed 12 October 2018].

Hornung, E. 2015. Railroads and growth in Prussia. *Journal of the European Economic Association*. 13(4):699–736.

Iversen, V & Ghorpade, Y. 2011. Misfortune, misfits and what the city gave and took: the stories of South-Indian child labour migrants 1935–2005. *Modern Asian Studies*. 45(05):1177–1226. doi.org/10.1017/S0026749X10000065.

Jaiswal, S. 2018. Looking beyond the idyllic representations of the rural: The Konkan Railway controversy and middle-class environmentalism in India. *Journal of Political Ecology*. 25(1):261–278. doi.org/http://dx.doi.org/10.2458/v25i1.22046.

Jaiswal, S & Bensch, G. 2018. A methodological framework to address gaps in the evidence on infrastructure impacts: the case of an Indian railway project evaluation. *Journal of Economic Methodology*. (December, 26):1–13. doi.org/10.1080/1350178X.2018.1561073.

Jalan, J & Ravallion, M. 1998a. Are there dynamic gains from a poor-area development program? *Journal of public economics*. 67(1):65–85.

Jalan, J & Ravallion, M. 1998b. Are there dynamic gains from a poor-area development program? *Journal of public economics*. 67(1):65–85.

Konkan Railway Corporation Limited. 1999. *A treatise on Konkan Railway*. Konkan Railway Corporation Limited.

Lehtonen, M. 2019. Ecological Economics and Opening up of Megaproject Appraisal: Lessons From Megaproject Scholarship and Topics for a Research Programme. *Ecological Economics*. 159:148–156. doi.org/10.1016/j.ecolecon.2019.01.018.

McKenzie, D. 2012. Beyond baseline and follow-up: The case for more T in experiments. *Journal of Development Economics*. 99(2):210–221. doi.org/10.1016/j.jdeveco.2012.01.002.

Michaels, G. 2008. The Effect of Trade on the Demand for Skill: Evidence from the Interstate Highway System. *Review of Economics and Statistics*. 90(4):683–701. doi.org/10.1162/rest.90.4.683.

Nanjundappa, DM & Sinha, RK. 1982. *Backward area development: problems & prospects*. Sterling.

Ozesmi, SL & Bauer, ME. 2002. Satellite remote sensing of wetlands. *Wetlands Ecology and Management*. 10(5):381–402. doi.org/10.1023/A:1020908432489.

Panandiker, VP & Ribeiro, E. 1993. Divert Konkan Railway to another track. *Times of India*. 13 May: 10.

Pawson, R. 2006. *Evidence-based policy: a realist perspective*. Sage.

Peter, B & Narendran, V. 2017. *God's Own Workforce: Unravelling Labour Migration to Kerala.* Kochi: Centre for Migration and Inclusive Development.

Railway Board. 2016. Social Service Obligation. In: *Indian Railways Year Book*. (Indian Railways Statistical Publications 2015-16). Ministry of Railways. Available from: http://www.indianrailways.gov.in/railwayboard/view_section.jsp?lang=0&id=0,1,304,366,554,1817,1819.

Ramjerdi, F & Fearnley, N. 2014. Risk and irreversibility of transport interventions. *Transportation Research Part A: Policy and Practice*. 60:31–39. doi.org/10.1016/j.tra.2013.10.014.

Rao, KR. 2016. Konkan Railway to start track-doubling, electrification work after the monsoon. *The Hindu Business Line*. 29 August. Available from: http://www.thehindubusinessline.com/economy/logistics/konkan-railway-to-start-trackdoubling-electrification-work-after-the-monsoon/article9046601.ece.

Report of the Expert Committee on Land Leasing. 2016. New Delhi: NITI Ayog, Government of India. Available from: http://niti.gov.in/content/report-expert-committee-land-leasing.

Rodrigue, J-P, Comtois, C & Slack, B. 2016. *The geography of transport systems*. Taylor & Francis.

Rodrigues, A. 1993. Opposition to Konkan Railway. *Times of India*. 13 May.

Rogers, PJ. 2008. Using Programme Theory to Evaluate Complicated and Complex Aspects of Interventions. *Evaluation*. 14(1):29–48. doi.org/10.1177/1356389007084674.

Rogers, PJ. 2009. Matching impact evaluation design to the nature of the intervention and the purpose of the evaluation. *Journal of Development Effectiveness*. 1(3):217–226. doi.org/10.1080/19439340903114636.

Sader, SA, Ahl, D & Liou, W-S. 1995. Accuracy of landsat-TM and GIS rule-based methods for forest wetland classification in Maine. *Remote Sensing of Environment*. 53(3):133–144. doi.org/10.1016/0034-4257(95)00085-F.

Sathiadhas, R & Prathap, KS. 2009. Employment Scenario and Labour Migration in Marine Fisheries. *Asian Fisheries Science*. 22(2):713–727.

Sequeira, S. 2011. Transport costs and firm behaviour: Evidence from Mozambique and South Africa. In: *Where to Spend the Next Million?: Applying Impact Evaluation to Trade Assistance*. O. Cadot, A. Fernandes, J. Gourdon, & A. Mattoo, Eds. London, UK: Centre for Economic Policy Research. 123–162.

Shankar, U. 1992. Is it on the right track? *Down to Earth*. (October, 31). Available from: http://www.downtoearth.org.in/indepth/is-it-on-the-right-track-30296.

Sharma, A & Chandrasekhar, S. 2014. Growth of the Urban Shadow, Spatial Distribution of Economic Activities, and Commuting by Workers in Rural and Urban India. *World Development*. 61:154–166. doi.org/10.1016/j.worlddev.2014.04.003.

Sita, K & Prabhu, KS. 1989. Levels of development and migration: Case of South Konkan. *Economic and Political Weekly*. 39–41.

Sorek, G. 2009. Migration costs, commuting costs and intercity population sorting. *Regional Science and Urban Economics*. 39(4):377–385. doi.org/10.1016/j.regsciurbeco.2009.03.003.

Thomas, JJ. 2014. The demographic challenge and employment growth in India. *Economic and Political Weekly*. 49(6):15–17.

Thorat, V, Dhekale, J, Patil, H & Tilekar, S. 2011. Determinants of rural-urban migration in Konkan region of Maharashtra. *Agricultural Economics Research Review*. 24:503–509.

Times News Network. 2016. *Konkan Railway rolls out plan for capacity doubling - Times of India*. Available from: http://timesofindia.indiatimes.com/city/mangaluru/Konkan-Railway-rolls-out-plan-for-capacity-doubling/articleshow/56145576.cms [Accessed 29 November 2017].

Tumbe, C. 2012. Migration persistence across twentieth century India. *Migration and Development*. 1(1):87–112. doi.org/10.1080/21632324.2012.716225.

Tumbe, C. 2015. Missing men, migration and labour markets: evidence from India. *The Indian Journal of Labour Economics*. 58(2):245–267. doi.org/10.1007/s41027-016-0017-4.

Wang, Y & Wu, B. 2015. Railways and the Local Economy: Evidence from Qingzang Railway. *Economic Development and Cultural Change*. 63(3):551–588. doi.org/10.1086/680091.

"When will the 'killer road' be commuter friendly?" 2017. *Herald* (Goa). 20 July. Available from: https://www.heraldgoa.in/Goa/South-Goa/When-will-the-%E2%80%98killer-road%E2%80%99-be-commuter-friendly/117856.html [Accessed 12 December 2018].

White, H. 2011. Achieving high-quality impact evaluation design through mixed methods: the case of infrastructure. *Journal of Development Effectiveness*. 3(1):131–144. doi.org/10.1080/19439342.2010.547588.

White, H & Phillips, D. 2012. Addressing attribution of cause and effect in small n impact evaluations: towards an integrated framework. *New Delhi: International Initiative for Impact Evaluation*.

Zhou, Y & Logan, J. 2007. Growth on the Edge: The New Chinese Metropolis. In: *Urban China in Transition*. J. Logan, Ed. London: Blackwell. 140–160.

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