Road Quality, Local Economic Activity, and Welfare: Evidence from Indonesia's Highways*

Paul J. Gertler[†]
University of California, Berkeley

Marco Gonzalez-Navarro[‡]
University of California, Berkeley

Tadeja Gračner[§]
RAND Corporation

Alexander D. Rothenberg[¶]
Syracuse University

May 2019

VERY PRELIMINARY - PLEASE DO NOT DISTRIBUTE

Abstract

This paper provides evidence of the effects of *road quality* on economic activity using temporal variation generated by road maintenance investments. A long panel of firms and households allows us to shed light on the effects of road quality for firms and pre-existing households. Methodologically, we propose a new road quality instrument using a nationwide panel dataset of road surface roughness to predict road quality from temporal variation in budgets exogenously allocated to different road maintenance authorities. We first show that higher road network quality leads to job creation in the manufacturing sector. We then show that this is reflected in household consumption and income. Third, we show evidence of an occupational shift from agriculture into manufacturing and improved profits for those who stay in agriculture. The gap in average income between agriculture and manufacturing employment is reduced with road quality but not eliminated.

*The authors thank seminar participants at UC Berkeley, Millenium Challenge Corporation, the RAND Corporation, University of Toronto, and University of Ottawa for helpful comments and suggestions. This work was generously supported by a USAID Economic Research Partnership Grant.

[†]Haas School of Business, MC #1900 Berkeley, California 94720. Email: gertler@haas.berkeley.edu.

[‡]Ag. Economics, MC 3310, Berkeley, California 94720. Email: marcog@berkeley.edu.

[§]1200 South Hayes St., Arlington, VA 22202-5050. Email: tgracner@rand.org.

[¶]426 Eggers Hall, Syracuse NY 13244-1020. Email: adrothen@maxwell.syr.edu.

1 Introduction

Maintaining and improving existing road networks, a major function of government, is often justified as a public good investment in economic activity and job creation. The vast majority public expenditures on roads is dedicated to maintenance and upgrading of existing roads, yet credible evidence on the economic impacts of this type of expenditure is sorely lacking in the literature.[1]

This paper aims to fill the existing gap in the literature regarding the effects of road quality on local economic activity and household welfare. We start by proposing a model of local road quality as a productive input into local firm and agricultural productivity. Modeling road quality as an input to productivity is motivated by the fact that road quality affects the costs of inputs as farmers use road networks to take produce to markets, firms use them to acquire inputs and deliver their output, and workers use them to reach their jobs. Road quality may also affect the organization of production. Better roads allow farmers to work on plots in more distant locations and share large equipment, firms can more easily source their workers and inventory from further locations, and they can more easily combine capital and labor. We hypothesize that improvements to road quality increase farm and firm productivity and profits. As a result, the demand for labor rises resulting in more employment. Firms and individuals may migrate into the area to take advantage of the better roads causing the price of land to rise.

The empirical analysis is made possible by an unusually long and comprehensive road quality administrative database collected by Indonesia's road authorities. Quality is measured annually for each road segment in the country using an international road roughness measure collected by sensors in vehicles as they travel along the roads. This administrative database tracks road-segment level quality for universe of Indonesia's highways over a 20 year period. We merge these data with a nationally representative household panel database and with the annual census of manufacturing firms.

In order to deal with identification, we propose a novel instrumental variable for road quality that takes advantage of Indonesia's centralized fiscal organization. National, provincial, and district government funds are almost entirely dependent on national revenues. This induces an large degree of independence of local government revenues from local economic activity shocks. Corresponding to each level of government, there are independent road authorities corresponding to each of the three levels of government (30 provinces and 400 districts). Importantly for our identification, in any given district, the share of roads of each type is predetermined. This induces temporal exogeneous variation in district road quality arising from the differential shares of road authorities operating in each district.

Using the manufacturing census, we find that higher local road network quality is associated with firm profitability and job creation in the manufacturing sector mostly through new firm

[1] Based on engineering models the World Bank (1994) estimates that the returns to road maintenance are twice as high as those for network expansion.

openings. We find no effect on manufacturing wages.

Using the Indonesia Family LIfe Survey, we observe an occupational shift from agriculture into manufacturing and higher profits for those who stay in agriculture. We also document increased returns to agriculture, and the gap in average earnings between agriculture and manufacturing employment is reduced but not eliminated. In terms of household welfare, we show that higher quality local roads lead to improvements in household consumption and income. More specifically, we show that one standard deviation improvement in road quality in a district results in a five percent increase in household consumption per capita, and an almost twenty percent increase in total labor earnings. Finally, using cross sectional district level census data, we provide some suggestive evidence that better local roads lead to small amounts of in-migration of households and higher land rents.

This research makes a number of important contributions to the literature. We are among the first to examine the effects of quality of existing roads. The previous literature has tended to focus on network expansions. Second, we focus on the effects of local roads on local markets as opposed to gains from trade due to lowering costs of transport between distant markets. Third, measuring changes in regional transport costs directly is difficult as there are no readily available datasets that document the evolution of the quality of transport infrastructure in developing countries.[2] In this sense, the road quality data we use represent a substantial improvement because they provide a very direct measure of transport infrastructure quality. Fourth, road improvements are typically not randomly assigned. This means that estimates of the effects of changes in transport costs may be confounded by the fact that areas receiving improvements were selected by policymakers for economic growth or expected growth reasons, creating simultaneity bias. We address the simultaneity problem by making use of the new instrument described above, which has the advantage of being replicable in many countries with centralized government revenues but decentralized expenditure decisions.

This paper relates to recent contributions to the empirical literature on the evaluation of transport infrastructure in developing countries. Qian et al (2012) find few effects of Chinese trunk roads among newly connected small counties in terms of GDP growth. Related work from Morten and Oliveira (2013) uses the construction of highways to the new capital city of Brasilia in the 1960s and documents that new roads generated growth of GDP, wages and additional migration. This paper is also related to Donaldson (2013) who estimates gains from trade from lower transport costs caused by the construction of India's railroads. The urban economics field has also produced substantial work using the U.S. interstate highway system expansion to analyze the effects of new highways. Duranton and Turner (2012) investigate city growth effects, Michaels (2008) analyzes skill premia changes, while Baum-Snow (2007) documents suburbanization effects.

The paper proceeds as follows: In section 2 we provide a theoretical framework, followed by the

[2]Previous approaches, widely used in the trade literature, involve *inferring* transport costs from a gravity equation, using data on regional trade flows (e.g. Anderson and Van Wincoop, 2004) or price differences (e.g. **?**).

section ??, which lays out the main datasets used. Section 3 describes the historical background on evolution of road quality and discusses the identification strategy. Section 5 presents the results and section 6 concludes.

2 Theoretical Framework

We conceptualize road quality as a village productive amenity, as in Jacoby (2000). The model we propose embeds a standard, prototypical model of the agricultural household (e.g. Singh et al., 1986; Benjamin, 1992; Bardhan and Udry, 1999) in a spatial general equilibrium model typically used in labor and urban economics (e.g. Rosen, 1979; Roback, 1982).

The economy is a collection of M discrete villages. Villages are each endowed with a single productive amenity, which we denote by A. In our application, we assume that villages with better roads have larger values of A. Without loss of generality, we can order these villages by their values of this productive amenity, as follows:

$$\underline{A} \equiv A_1 < A_2 < ... < A_M \equiv \overline{A}$$

There are two types of agents in the model: firms, which make use of land and labor in constant-returns-to-scale production, and household-workers, which decide how to allocate land and labor between farming and off-farm employment. We describe the objectives and constraints of each of these agents in the next subsections. The objective of this section is to provide a conceptual framework within which to interpret the empirical analysis.

2.1 Firms

Firms produce a composite good, X, under a constant-returns-to-scale production environment. The good is freely traded over space, and without loss of generality, we can normalize output prices to 1 (the model's numeraire). Firms use capital, labor, and land for production. For simplicity, we assume that capital is freely traded over space at rate ρ, and we also assume that each firm inelastically demands a single unit of land for production. Both rents, r, and wages, w, vary across locations and are determined in equilibrium. The firm's problem is to choose a cost-minimizing quantity of labor, L^M, to satisfy production requirements.

Crucially, we assume that there is some value of the productive amenity, $\widetilde{A}$, such that if a village has $A < \widetilde{A}$, no firm production will take place. At values of $A < \widetilde{A}$, firms will not be able to produce output with *any* amounts of capital or labor. This amenity threshold introduces non-concavity in an otherwise standard production function. We can write the firm's problem as follows:

$$\min_{L^M,K} wL^M + \rho K + r \qquad \text{subject to} \tag{1}$$

$$X = \begin{cases} 0 & if A < \widetilde{A} \\ G\left(L^M, K, 1;\ A\right) & if A \geq \widetilde{A} \end{cases} \tag{2}$$

Optimal choices of inputs lead to cost minimization. This yields a cost function, denoted by, $C(w, r; A, \rho)$, which maps wages, rents, the price of capital, and the value of the amenity into the minimized value of production costs. Because of free entry, firms in locations where $A \geq \widetilde{A}$ will produce until the point where production costs equal output prices (which are normalized to 1). This gives us the following equilibrium condition:

$$C(w, r; A, \rho) = \begin{cases} \infty & A < \widetilde{A} \\ 1 & A \geq \widetilde{A} \end{cases} \tag{3}$$

Note that because the price of capital is equal over space, ρ is a parameter in this expression. By applying Sheppard's Lemma to the convex portion of the cost function, we obtain the following expression for labor demand:

$$L_d^{M*} = \begin{cases} 0 & A < \widetilde{A} \\ C_w(w, r; A, \rho) & A \geq \widetilde{A} \end{cases}$$

2.2 Households

For simplicity, we assume that agricultural households are unitary, abstracting from intra-household resource allocation considerations. In each village, households inelastically demand a single unit of land, which they rent at rate r and use for farming. Households choose quantities of consumption, C, and decide how to allocate their labor endowment, E^L, between working on the farm, L^F, and working for a firm, L^M. Conditional on the choice of a location, indexed by A, the household's problem can be stated as follows:

$$\max_{C,L^M,L^F} U(C) \qquad \text{subject to} \tag{4}$$

$$C \leq F\left(L^F, 1;\ A\right) - r + wL^M \tag{5}$$

$$E^L = L^M + L^F \tag{6}$$

where the utility function, $U(\cdot)$, is assumed to be continuously differentiable, with $U'(\cdot) > 0$, and $U''(\cdot) < 0$, and $F\left(L^F, 1;\ A\right)$ is the farm production function. We assume that $F_A > 0$, as higher A

leads directly to higher farm output per unit of input, or it may lower input prices.[3] Equation (5) is the full income constraint, stating that the value of the household's consumption cannot exceed the value of farm profits plus off-farm labor earnings.

Equation (6) is the labor resource constraint, stating that the household's total labor endowment is equal to the total amounts of labor supplied to the market and to the farm. Implicitly, we are assuming that the household does not value leisure and that there is no unemployment. If individuals cannot spend their entire endowment of labor in off-farm employment, they must spend the rest of their time farming. Under this assumption changes in A have no effects on the extensive (probability of working) or intensive (hours of work) margins of labor supply.

Note that we also assume, for simplicity, that labor on the farm can only be directly supplied by the individual farmer household. This makes sense in a rural context with large families and contracting imperfections. We solve the household's problem in two cases, depending on the value of the amenity. If $A \geq \widetilde{A}$, then there is no job rationing, and the agricultural household model is separable. Following Benjamin (1992), we solve the model recursively. The household first chooses quantities of labor and land to maximize farm profits, which yields the farm's profit function:

$$\pi^* (w, r\,;\, A) = \max_{L^F} F\left(L^F, 1\,;\, A\right) - wL^F - r$$

This gives us the household's income, which we can write as:

$$M^* = \pi^* (w, r\,;\, A) + wE$$

Optimal choices of consumption lead to an indirect utility function, which maps income and prices into the maximum amount of household utility that can be attained:

$$\begin{aligned} V &= \widetilde{\psi} \left(\pi^* (w, r\,;\, A) + wE\right) \\ &\equiv \psi (w, r\,;\, A) \end{aligned} \tag{7}$$

On the other hand, if $A < \widetilde{A}$, then there are no off-farm employment opportunities for work, and $L^M = 0$. The household's supplies all of its labor to the farm, yielding the following value of income and consumption:

$$C = F\left(E^L, 1\,;\, A\right) - r$$

This implies that the farmer's indirect utility is:

$$\begin{aligned} V &= \widetilde{\psi} \left(F\left(E^L, 1\,;\, A\right) - r\right) \\ &= \psi (w, r\,;\, A) \end{aligned}$$

[3]Note that the consumer-farmer-worker does not obtain utility for services provided by housing. Nor does the household's utility depend on A directly. The entire consumer amenity aspect of A comes through the dependence of household indirect utility on the farm production function, $F(\cdot)$.

In locations where $A < \widetilde{A}$, at some wage levels, workers may want to supply labor to the market. This could be because at some level of farming labor, $L^{F*} \leq E^L$, the marginal product of labor is zero. However, because of the absence of non-farm employment opportunities, the household supplies its entire labor endowment to the farm. The combination of non-concavity in the manufacturing production function with respect to A and eventual zero marginal product of labor in farming creates dual labor markets (Sen, 1966; Dickens and Lang, 1985).

If migration is costless, workers will be perfectly mobile across locations, so that the following must hold:

$$\overline{V} \equiv \psi\left(w, r\,;\, A\right) \text{ for all } A \tag{8}$$

This means that indirect utility will be equalized over all locations in space, even low amenity villages. In such villages, rents must be low enough to compensate workers for living there. On the other hand, if migration is costly, there can be a wedge in utility across space.

2.3 Land Markets

Both farmers and firms inelastically demand a single unit of land, which they rent at rate r. Land is supplied on a spot market, according to marginal cost, so that:

$$r = h'\left(N_f + N\right) \tag{9}$$

where N_f is equal to the number of firms, N is equal to the number of agricultural households, and $h\left(\cdot\right)$ represents the total cost of clearing land for production and dividing into plots. We assume that $h\left(\cdot\right)$ is increasing and strictly convex in the total population of firms and households, $N_f + N$.

2.4 Spatial General Equilibrium

We consider spatial equilibrium conditions to hold in the long-run. Firms are created and labor reallocates, and as this occurs, wages and rents will adjust to equalize production costs and indirect utility over space. Mobility provides us with three equilibrium conditions: (3), (8), and (9). Using these, we can show a series of propositions from the model. We first show that because A is a productive amenity, increases in A will result in an entry of firms and an in-migration of households.

We can implicitly differentiate the equilibrium conditions, (3), (8), and (9), and solve for the comparative statics.

$$\begin{bmatrix} C_w & C_r & 0 \\ \psi_w & \psi_r & 0 \\ 0 & -1 & h''(\cdot) \end{bmatrix} \begin{bmatrix} \partial w/\partial A \\ \partial r/\partial A \\ \partial\left(N_f + N\right)/\partial A \end{bmatrix} = \begin{bmatrix} -C_A \\ -\psi_A \\ 0 \end{bmatrix}$$

Solving the second equation gives:

$$\frac{\partial r}{\partial A} = \frac{1}{\Delta}\left(\underset{+}{C_w}\underset{+}{\psi_A} - \underset{-}{C_A}\underset{+}{\psi_w}\right) > 0$$

where the denominator, Δ, is positive and given by:

$$\Delta = \underset{+}{\psi_w}\underset{+}{C_r} - \underset{+}{C_w}\underset{-}{\psi_r} > 0$$

So that increasing A leads to increases in land values (rents). The inmigration of firms and workers will increase the demand for land in the affected areas. This will lead to an unambiguous increases in the values of land and land rents.

Solving for the first equation gives:

$$\frac{\partial w}{\partial A} = \frac{1}{\Delta}\left(\underset{-}{C_A}\underset{-}{\psi_r} - \underset{+}{C_r}\underset{+}{\psi_A}\right) \gtrless 0$$

So that increasing A leads to ambiguous effects on wages. Note that in low amenity villages, the marginal product of agricultural labor is very low because households in these villages allocate their entire labor endowment to the farm. Road improvements in these villages can attract some labor labor away from farming without raising wages. It is straightforward to see that the model predicts an increasing number of firms and consumption when road quality increases.

3 Background

3.1 Road Quality Data

Every year, the Indonesian Department of Public Works (*Departemen Pekerjaan Umum* or DPU) conducts a high resolution data collection effort to monitor pavement quality as part of Indonesia's Integrated Road Management System (IRMS). These measurements are conducted by a team of surveyors who collect information on each road segment including surface type, width and roughness. Roughness is measured in terms of vehicle suspension motion collected by driving standardized vehicles fitted with instruments to measure suspension motion as the vehicle travels on roads at standardized speeds. The dataset includes this information for the universe of Indonesian district, provincial and national roads for the years 1990-2007, and contains more than 1.2 million kilometer-post-interval-year observations. These data were merged into the shapefiles (map) of the road networks that provides us with an annual panel of road quality measures along the whole network of Indonesian national, provincial and district roads for the years 1990-2007.

Our measure of road quality is the international (road) roughness index (IRI), a widely accepted measure of road quality in civil engineering, developed by the World Bank in the 1980s.[4] The IRI is defined as the ratio of a vehicle's accumulated suspension motion in meters, divided by the distance traveled by the vehicle during measurement in kilometers. All else equal, when driving on inferior roads such as gravel roads or when faced with potholes and ragged pavement, drivers prolong their travel time through decreased travel speed, augment their likelihood of being involved in an accident, wear down cars to a larger extent, and consume more fuel. Consequently, road roughness is directly related to transport costs both in terms of time and cost.[5]

Our main measure of local road quality is the negative of the distance-weighted average of roughness for all roads in district d. Let $r = 1, ..., R(d)$ index road segments in district d, and let d_r denote the length of the road segment r. Our average road quality measure is defined as:

$$\text{Road quality}_{dt} = -\frac{\sum_{r=1}^{R} d_r \text{IRI}_{rdt}}{\sum_{r=1}^{R} d_r} \tag{10}$$

where IRI_{rdt} denotes the road roughness of road section r in a district d at time t. Importantly, this is an average across national, provincial and district roads located in the district, and different districts have different shares of each of these types of roads. We merge the data of road quality measure with a digital map of the road network, which yields a panel of road quality measures used for our empirical analysis.

Figure 1 shows substantial variation in road quality over time, observed in a significant leftward shift in the distribution of road roughness across districts between 1990 and 2000. Similarly, Figure 2 documents substantial spatial variation in road improvements over time on the Island of Sumatra. For instance, the road network went from 84 percent of unpaved roads in 1990 to only 46 unpaved roads only a decade later. Similar trends apply to Java's highway network.[6] Finally, Figure 3 shows how that the distribution of road quality substantially narrowed between 1990 and 2007, suggesting that the improvements in road quality came from upgrading the poor quality end of the distribution.

3.2 Indonesian Life Panel Survey

Our main data source for the individual and household outcome level analysis, such as individual labor market outcomes, and household income and consumption, is the Indonesian Family Life Survey (IFLS). The IFLS is a nationally representative longitudinal survey that was collected in 1993, 1997, 2000 and 2007. The IFLS is representative of 83 percent of Indonesia's total population and follows more than 30,000 individuals over a 14-year period. These individuals are observed

[4] See Appendix Section **??** for more details on the IRI.

[5] Fuel consumption and labor costs account for more than 50 percent of vehicle operating costs in Indonesia (Asia Foundation, 2008).

[6] See Appendix Figure **??** and Appendix Figure **??**.

in more than 300 villages (*desa*), which are located in 13 of Indonesia's 27 provinces over 200 municipalities (*kabupaten*). Figure 4 shows the locations of IFLS villages used throughout our analysis. The IFLS is notable for its low attrition rate, as more than 87 percent of the original households are tracked through all four waves of the survey. Consequently, this panel data allows us to track the same households and individuals facing different road infrastructure conditions over almost twenty years.

3.3 Census of Manufacturing Firms

Our primary data source for firm-level outcomes is the Indonesia Annual Census of Manufacturing Establishments (*Survei Tahunan Perusahaan Industri Pengolahan*, or SI), collected by Indonesia's central statistical agency, (*Badan Pusat Statistik* or BPS). The SI is an annual census of manufacturing plants with more than 20 employees and contains detailed information on plant's cost variables, their industry of operation, employment size and measures of value added. An advantage of SI data is that it contains firm-level identifiers, allowing us to track changes in firm-level outcomes over time. The data contains information on the firm's starting date and its location at the district level, as well as firm-level outcomes, such as employment and wage rates, value added, output, and total factor productivity.[7]

3.4 Population Census

We combine these sources with the 2000 Population census as well. This data source is used for a district-level analysis on migration and wages as outcomes of interest, as it collects individuals' birth districts, and their socio-demographics, including wages.

4 Empirical Strategy

Our objective is to identify the causal effect of road quality on outcomes of interest. To do so we estimate the following regression model:

$$y_{dt} = \alpha_d + \alpha_t + \beta \log \left(\text{Road Quality}\right)_{dt} + \mathbf{x}'_{dt}\theta + \varepsilon_{dt}, \tag{11}$$

where y_{dt} is the outcome of interest observed in district d at time t. The variable $\log\left(\text{Road Quality}\right)_{dt}$ measures the negative of the log of the average roughness for all roads in a district d at a time t. The vector $\mathbf{x}_{dt}$ represents a set of time-varying controls, including non-oil district level GDP, and log of population. Panel data allow us to control for time-invariant unobservables that may be

[7]New firms are counted when they appear in the dataset having never appeared before. Also, for the purpose of our analysis, we dropped all firms coded as state-owned enterprises (less than 3 percent of all firm-year observations). Throughout the discussion, we use plants and firms interchangeably since less than 5% of plants in the dataset are operated by multi-plant firms (Blalock and Gertler, 2008).

correlated with changes in road quality and outcomes of interest through district and time (year-Island) fixed effects, or α_d and α_t respectively. Standard errors are clustered at the district level. We estimate this regression model at the individual and household level as well - in that case, we include corresponding control variables and individual or household fixed effects, respectively.

As road quality was not randomly assigned, OLS and even district fixed effects estimates may be biased. In areas were roads are used more, road quality is likely to deteriorate faster. High road use in areas with faster economic growth creates feedback from economic outcomes to road quality. Similarly, governments targeting of upgrades to areas where road deteriorate faster again likely creates feedback from economic activity to road quality. Neither of these problems are completely solved with time and location fixed effects.

We can describe both concerns using a capital accumulation formation of the evolution of quality in equation form below:

$$\text{Road Quality}_{rt} = \text{Road Quality}_{r,t-1} \cdot (1 - \delta) + \alpha I_{rt} \tag{12}$$

where r defines a road segment, δ denotes road quality deterioration rate, and I_{rt} is investment in segment r at time t. Instead of specifying a fixed per-period deterioration rate, suppose for a greater usage to cause road quality to deterioriate more rapidly:

$$\delta_{rt} = f\left(\text{Use}_{rt}\right)$$

Then, we can write $f(\cdot)$, where $\delta_{rt} = \phi_1 + \phi_2\, Use_{rt}$, to estimate:

$$\text{Road Quality}_{rt} = \text{Road Quality}_{r,t-1} \cdot (1 - \phi_1 - \phi_2\, \text{Use}_{rt}) + \alpha I_{rt} \tag{13}$$

Equations (12) and (13) show that estimates of the effects of changes in road quality may be confounded: areas receiving improvement investment ($\uparrow I_{rt}$) might have been selected by policy-makers because of previous rapid deterioration or for economic growth or expected growth reasons. Second, if better roads increase local economic activity, then feedback may generate attenuation bias as roads may deteriorate faster due to their extensive use ($\uparrow Use_{rt}$).

To address these concerns, we use an instrumental variables approach from the investments side of the determinants of roads quality. Indonesia used a two-stage budgeting process where budgets were allocated to local authorities that then decided how to allocate those budgets to specific road segments. While the second stage is clearly endogenous, we show in the next section that the first stage, i.e. the budget allocations to local road authorities, is plausibly exogenous and is a good instrument for road quality. To construct this instrument, we take advantage of Indonesian administrative decision-making process for road maintenance investment decisions. We describe this process and instrumental variables used in details in the following sections.

4.1 Road Maintenance Financing and Allocation

During their rule, Dutch colonists built and maintained much of today's road network. After independence in 1945, roads were left to deteriorate until 1967, when Suharto assumed power. Road rehabilitation and improvement then became a top priority, and was explicitly built into the five-year development plans (Repelita*Repelita*). Spending on roads increased rapidly until the late 1970s and then slowed in response the collapse of state oil revenues, and remained stagnate through the 1980s. In the early 1990's, manufacturing began to grow rapidly and the rehabilitation and upgrading of roads became a priority.

The total budget for road improvements almost doubled from $2.1 in the late 1980s to $3.9 billion in the early 1990s.[8] Almost all of the expenditures were allocated to improving the existing road network, especially upgrading dirt roads to asphalt. Although expenditures were planned to be kept at high levels during Repelita VI (1994-1999), the Asian financial crisis and its concurrent political upheaval resulted in less spending than originally intended. Road expenditures have experienced a slow recovery ever since (World Bank, 2012).

Road maintenance and upgrading are primarily financed through the central government's budget Green (2005). [9] Figure 5 shows the growth in revenues and expenditures for road maintenance at a national and regional level over time. Until 2000, almost all of the financing came from central Government, after which the regional public budget share rose modestly (Green, 2005; World Bank, 2012).

While the central government finances road maintenance, local governmental units are responsible for the actual maintenance. The central Government transfers funds to provincial and district governments for them to use to maintain their roads at their discretion. The central government also transfers funds to other provincial level units responsible for the national roads in their province. Hence, road investment decisions can be thought of as following a two-stage budgeting procedure (Deaton and Muellbauer, 1980), where the central government sets the budget for each subnational unit to then allocate and spend.

The central government allocates its roads budget to local units using a formula that is publicly available. The formula depends on factors such as area, population, length and density of roads, and the cost of maintenance. The formulas are set in Jakarta with no local input nor are there annual negotiations with local governments over the allocations. The formulas are designed to help to equalize the fiscal capacities of sub-national governments, to subsidize poorer more remote areas, and are aligned with the national priorities stated in Repelitas (Bird and Smart, 2001).

Both the criteria and weights in the budget allocation formula changed every few years (Bird and Smart, 2001). In particular, the criteria and weights differed significantly in periods before and

[8]These numbers are taken from various planning documents describing Indonesia's five year development plans. They are expressed in 2000 constant U.S. dollars.

[9]The government raises more than 90 percent of total local government revenues from the tax on natural resources, followed by the income tax, VAT and luxury tax (Green, 2005; World Bank, 2012).

after 2000 when the government decentralized many of its functions to local governments. Prior to 2000, there was substantial year-to-year variation in the weights but not in the criteria (Figure 6). After 2000, central financing came from 2 sources: more than 85 percent of road expenditures were financed through the Dana Alokasi Umum (DAU) or General Allocation Grant, and the remainder came through the Daka Alokasi Khusus, (DAK) or Special Allocation Grant. Both are allocated to local units based on national formulas, where both the criteria and weights changed every few years. The criteria and weights for the DAK are in Figure 8) and for the DAU in Figure 7. [10] Most of the changes in the weights were driven by the decentralization laws and in order to speed up compliance with national priorities of improving equal economic development (World Bank, 2008). An additional source of variation in road budgets came from changes in the criteria included in the formula - for instance, the human development index and GDP criteria replaced the poverty index criteria in 2006 (World Bank, 2012).

In the *second* step, local governments use their allocated funds to upgrade roads of their choosing independently from the central government. One of the official criteria for the intergovernmental transfers claims that: ..."The subnational governments should have independence and flexibility in setting their priorities. They should not be constrained by the categorical structure of the programs and uncertainty associated with decision-making at the Center"... (Shah et al. (1994), p.72). Crucial for our identification strategy, this implies independence between the first and the second stage in road upgrade decision-making.[11]

Given this contextual evidence, temporal variation in local road budgets is plausibly exogenous to changes in local economic activity. While in the cross-section budget allocations may be driven in part by variation in local economic conditions, changes in local budgets over time are not. The variation in changes in local budgets over time is driven by changes in national tax revenues, changes in the criteria and weights in the allocation formulas, and by the fact that different districts have different shares of national, provincial and district roads and that each of these units has different national budget allocations.

4.2 Local Road Budget Measurment

We construct an objective measure to approximate the total budget for national, provincial, and district road investments using the road roughness measure, described in sections above.[12] Let r index roads, A index road maintenance authorities (National, Provincial, or District), and let t index years. Let $R(A)$ denote the set of roads under maintenance by authority A. Let U_{rt} denote

[10]For more details on revenue sources over time see Figure 9.

[11]Law 22/99 specifies the tasks that a district must perform, and those involve health, education and local infrastructure. Local discretion is restricted to the repair and upgrading of existing roads. New roads require central approval **?**. For more details, see Figure 10.

[12]We do not use direct data on the amounts allocated to roads, as these may not be so informative about actual road improvements given corruption and monitoring issues common to developing countries (Olken, 2007).

an indicator for whether or not road r was upgraded between $t-1$ and t:

$$U_{rt} = \mathbf{1}\{\mathrm{IRI}_{r,t} < \mathrm{IRI}_{r,t-1}\}$$

We then construct a variable that can be interpreted as the road maintenance budget for different road authorities as follows:

$$\widetilde{B}_t^A = \sum_{r \in R(A)} d_r U_{rt} \times (\mathrm{IRI}_{r,t-1} - \mathrm{IRI}_{r,t})$$

where d_r denotes the length of segment r and $R(A)$ denotes the set of roads under road authority A's purview. In words, the budget for road improvements $\widetilde{B}_t^A$ for administrative authority A in year t equals total kilometers of roads upgraded in year t that are administered by authority A, weighted by the change in IRI of each road segment. This implies that larger improvements in road quality represent a larger budget spent improving the road. If costs of upgrading are approximately linear, then weighting the upgrading indicator by the change in road roughness should be a good proxy for the total amount of expenditures on roads by the authority.

4.3 Instrumental Variable Validity

In this subsection we show that road budgets conditional on district and time fixed effects are predictive of road quality and the lagged economic activity are not predictive of road budgets. In our data, there are 17 national road offices - one in each province, 17 provinces, and 218 districts. Each district, indexed by d, is a part of a province, $p(d)$. We have the following budget variables:

1. $\widetilde{B}_{p(d)t}^N$: The budget for national roads in province $p(d)$ between $t-1$ and t.
2. $\widetilde{B}_{p(d)t}^{p(d)}$: The budget for provincial roads in province $p(d)$ between $t-1$ and t.
3. $\widetilde{B}_{dt}^d$: The budget for district roads in district d between $t-1$ and t.

For road budgets to be relevant instruments, local budgets should be strong predictors of road quality. To assess this we estimate a version of equation (13). Specifically, we regress a districts road quality against last year's road quality, years since last upgraded in quadratic form, and the budget variables. Table 1 shows that budgets for all types of roads in the province (district) are indeed strongly correlated to road quality in the province (district). The coefficients are of expected sign and show that larger budgets of road authorities imply improved road quality. This confirms the relevance of our instrument for road quality.

As mentioned, in the first stage the Center allocates budgets using a national formula, and in the second stage of the budgeting process the local road authorities decide which roads to upgrade. For road budgets to satisfy the exclusion restriction, they have to be uncorrelated with local economic conditions. We provide empirical evidence that this is the case by regressing budgets against lagged economic activity. Since budgets for period t are formed in period t-1, we regress the budgets against indicators of economic activity in period t-2 plus district and year fixed effects. In particular, we regress the road budget of provincial road authorities against the lagged province GDP or lagged number of firms (see Table 2). Table 2 shows that budgets allocated to local authorities are indeed orthogonal to local economic conditions. This increases our confidence that the exclusion restriction of our proposed instrument at the district level is satisfied and the financing of the first stage is indeed compliant with institutional setting described above.

5 Results

Before showing the main results, we first provide evidence that road quality is indeed correlated to travel times as reported in the IFLS survey. The survey asks for self-reported travel time to the nearest city and the nearest provincial capital. In Table 3 we show that indeed there is a strong correlation between road quality (our main regressor of interest) and self reported travel times.

5.1 Road Quality and District-Level Manufacturing Outcomes

We begin by showing panel regressions of district-level average manufacturing outcomes. The regression of interest is:

$$y_{dt} = \alpha_d + \alpha_t + \beta \log(\text{Road Quality}_{dt}) + \mathbf{x}'_{dt}\theta + \varepsilon_{dt}$$

Where α_d and α_t are district and year fixed effects respectively, $\log(\text{Road Quality}_{dt})$ is the negative of log roughness of the road network in district d in year t, $\mathbf{x}_{dt}$ are time varying district characteristics and ε_{dt} is the error term. Standard error are clustered at the district level. As explained in the estimation section, we instrument district road roughness with two instrumental variables (national roads budget and provincial roads budget: B_t^A for $A = N, p(d)$).

Table 4 shows the district-level manufacturing results. Column 1 shows the fixed effect OLS estimation, column 2 shows the instrumented GMM estimates and columns 3, 4 and 5 show the number of observations, the mean of the dependent variable and the Kliebergen-Paap weak instruments rk F-statistic. Each row reports results from a separate regression. We show the OLS fixed effects estimates for comparison, but we focus our discussion on the IV-GMM ones in column 2.

The top panel describes the effects of road quality on the existence and quantity of manufacturing firms in the district. The estimation shows that the dummy for whether a manufacturing establishment exists in the district improves by 0.27 log points (31%) with a log unit increase in district road quality. The net number of firms goes up by 0.356 log points (row 4), and this is driven by the opening of firms (row 2) rather than reduced closure of firms (row 3).

The second panel shows that district level log manufacturing output increases significantly with road quality (row 5) - the elasticity of output with respect to road quality is 3.86. A similar magnitude arises if we measure output using value added (elasticity of 3.43).

This is explained through increased investment (row 7) which shows that manufacturing investment has an elasticity of 3.35. A first indication that local roads function as a local production amenity is the fact that there is no change in the share of firms that export.[13]

The last row in the middle panel shows results for total factor productivity (TFP) which is constructed from estimating firm-level production functions using the Levinsohn and Petrin (2003) control-function approach as documented in Poczter et al. (2014). The elasticity of TFP with respect to road quality is found to be around 0.8. The first two panels provide strong evidence that the number of manufacturing firms together with output and investment respond strongly to changes in local road quality.

In terms of district level manufacturing employment outcomes, the lower panel in Table 4 shows that elasticity with respect to road quality is almost one. We also find that the log output per worker as well as the log value added per worker show a positive elasticity of 0.908 and 0.738 respectively. On the other hand, there is no significant effect on wages. This is somewhat surprising and poses the question of whether manufacturing labor expansion can be sustained without increases in wages. We will explore these results further at the the household level in the following sections. We find that manufacturing jobs are relatively more desirable than those in other sectors, which makes workers willing to switch to manufacturing employment when opportunities arise at the prevailing wages.

5.2 Road Quality and Firm-Level Manufacturing Outcomes

Whereas the previous table described district level effects of road quality, we now turn to firm-level effects. The specification we use in Table 5 is:

$$y_{idt} = \alpha_i + \alpha_t + \beta \log\left(RoadQuality_{dt}\right) + \mathbf{x}'_{idt}\theta + \varepsilon_{idt}$$

where idt refers to firm i in district d at time t. The specification is now based on over 250,000 firm$X$year observations over the 1991-2007 period and includes firm and year fixed effects.[14] The dependent variables we analyze are log output, log value added, log total firm labor, log wages, log investment, exporter indicator, output per worker, log value added per worker and log total factor productivity. In all cases we find insignificant effects of road quality.[15] This Table together

[13]The investment and FDI variables are undefined from 2002-2005 and 2007. This is because of changes to the questionnaire, which also explains the drop in sample size.

[14]Controls include logs of current population and non-oil GDRP.

[15]Again, the investment and FDI variables are undefined from 2002-2005 and 2007. This is because of changes to the questionnaire, which again also explains the drop in sample size.

with the previous one, which shows significant effects for the district as a whole, indicate that road quality affects the extensive margin of firm creation, but has no significant effect on the pre-existing firms.

5.3 Road Quality and Individual-Level Outcomes

To better the understanding of the firm and wage results presented in sections above, we next turn to explore the effects of roads on individual level labor market outcomes using the IFLS. These data track individuals over time and are based on approximately 36,000 person$X$survey wave observations. We estimate individual level fixed effects regressions in which the estimating equation is:

$$y_{idt} = \alpha_i + \alpha_t + \beta \log \text{Road Quality}_{dt} + \mathbf{x}'_{dt}\theta + \varepsilon_{idt}$$

Included in $\mathbf{x}_{dt}$ are controls for current levels of population, levels of GRDP, survey wave indicators, survey month indicators, and controls for household size, individual age, and individual education. Because outcomes are only observed approximately every 3 years (e.g. 1993, 1997, 2000, 2007), we instrument current roughness with the usual budget IVs, but include 2 lags of the IVs as well. The IVs we use are: B_t^A, B_{t-1}^A, and B_{t-2}^A for $A = N, p(d)$.

The top panel in Table 6 shows that neither employment probability or hours worked changes significantly with road quality. In contrast, we see large and statistically significant effects for log earnings [16]. For every log point improvement in road quality, log individual earnings are estimated to rise by 0.91 log points (p-value <5%).

In the lower panels we investigate what drives the increased total worker earnings. Specifically, the bottom five panels decompose the likelihood of working in any given sector. The first thing to notice is that improved roads lead to a substantial reduction in the likelihood of working in the agricultural sector by 8.5% for every log point improvement in road quality (The effect is significant at the 5% level). The same holds true for the likelihood of working in the sales and services sector and 'other informal' sector.

The reduction in the likelihood of being employed in the agricultural, sales and services and other informal sectors is in stark contrast to the a 10% larger probability of being employed in the manufacturing sector when roads improve by the same degree. This is a key finding of the paper. First, this result shows the household counterpart to the increased manufacturing employment described in Table 4. Second, it shows that labor in the manufacturing sector is being drawn from the agricultural and services sectors, which pay lower average wage than manufacturing. This phenomenon is consistent with local road quality playing a crucial role in the development of an economy.

The log earnings rows (which control for hours worked, where hours worked are only defined for people who are working) show that conditional on working on the sector of employment, road

[16] $Log\ Earnings = Log(Earnings + 1)$.

quality improves labor earnings in the agricultural sector, but not in the manufacturing sector. This again is consistent with the lack of wage effects documented in Table 4. It also points to a reduction in the income gap between the agricultural and the manufacturing sector when roads improve.

5.4 Road Quality and Household-Level Outcomes

How are these individual level labor market outcomes reflected in household welfare? In Table 7 we report results on the effects of road quality on per capita consumption. The elasticity of consumption to road quality is 0.18, based on 23,000 household$X$year level observations. Importantly, this estimate refers to the same household over time, meaning that it is not confounded by migration effects.[17]

The second row in Table 7 provides evidence on the effects of road quality on land value. For the land value regression, we include controls for the number of rooms, whether the house has electricity, piped water, its own toilet, indicators for types of floor (cement, dirt), walls (masonry), and a tiled roof.[18] We find that the elasticity of land value to road quality is approximately one. This points to road quality being capitalized into local land values (c.f. Gonzalez-Navarro and Quintana-Domeque, forthcoming - TO INCLUDE IN BIBTEX).

In the last row, we also report effects on rent per room. This can be seen as a robustness check for the land values effect. For the log rent regression, we also include an indicator for whether the rent observed is actual (as opposed to estimated). Comfortingly, it also has a large and statistically significant relationship with road quality: the elasticity on rent per room is 0.726. In short, both indicators show that road quality gets capitalized into local land values.

5.5 Road Quality and District-Level Migration Outcomes

We next provide evidence on the effects of road quality on immigration to the district in Table 8. These are cross-sectional regressions of district-level outcomes with province fixed effects. We regress the outcome variable, y_d, on changes in road roughness from 2000-1995 using the following specification:

$$y_d = \alpha_{p(d)} + \beta \log \Delta \text{Road Quality}_{d,2000-1995} + \mathbf{x}_d' \theta + \varepsilon_d$$

[17]As before, these are panel regressions with household fixed effects. We regress the outcome variable, y_{hdt}, on levels of road roughness in year t. The estimated regression is:

$$y_{hdt} = \alpha_h + \alpha_t + \beta \log \text{IRI}_{dt} + \mathbf{x}_{dt}' \theta + \varepsilon_{dt}$$

and included in $\mathbf{x}_d$ are controls for current levels of population, levels of GDRP, survey wave indicators, survey month indicators, and controls for household size.

[18]Because outcomes are only observed every 3 years or so (e.g. 1993, 1997, 2000, 2007), we instrument current roughness with the usual budget IVs, but include 2 lags of the IVs as well. The IVs we use are: B_t^A, B_{t-1}^A, and B_{t-2}^A for $A = N, p(d)$.

where included in $\mathbf{x}_d$ are controls for 1990 levels of population and 1990 levels of GDRP. In the regression, we instrument the 5-year change in roughness with the usual budget IVs, but include 2 lags of the IVs as well. The IVs we use are: B_t^A for $t = 2000, 1999, 1998$ and $A = N, p(d)$.

The first row in Table 8 shows that indeed districts with improved road quality improvements experience a significantly larger although modest population growth rate (the elasticity is 0.069). This is also reflected in the more direct measure of log share of recent migrants (individuals who moved in the last 5 years) or log total recent migrants with elasticities of 1.4 and 1.6 respectively. These cross-sectional estimates are less well identified than those in the rest of the paper, but nevertheless they provide some suggestive evidence of the positive effects of roads on migration.

5.6 Road Quality and Prices

In this paper we argue that the local road quality can serve as a productive input - road quality changes can affect quantities being produced and consumed without necessarily being reflected in price changes due to transportation costs changes, as suggested in the trade literature so far (Donaldson, forthcoming).

We investigate whether road quality affects prices significantly in Table 9. The table shows results using the panel of IFLS communities as well as controls for log of population and non-oil GDRP. Log food price is a Laspeyres price index composed of community level prices of rice, oil sugar, salt (tradables), beef and fish (perishables) with corresponding initial consumption expenditure weights.

The table shows there is no clear correlation with wages, food prices, nor tradables prices. The only significant effect is observed for perishables, suggesting a reduction in prices. This Table is consistent with the roads being an input to production rather than affecting relative prices for tradables.

We can take this idea further and compare the effects we document in the paper against the more traditional market potential measure in the urban literature (c.f. Donaldson and Hornbeck, forthcoming). We construct a market access measure of road quality taking into account road quality to the nearest provincial capital as well. Let $\mathcal{I}(d)$ denote the set of *other* districts on district d's island (Sumatra, Java, Sulawesi). Importantly, $d \notin \mathcal{I}(d)$. We define district d's *Island Market Potential* as follows:

$$\text{Island MP}_{dt} = \sum_{r \in \mathcal{I}(d)} \frac{Y_{rt}}{\tau_{rdt}}$$

where Y_{dt} is district d's gross domestic regional product in year t, and τ_{rdt} is the roughness-based travel time from district r to district d in year t. This is a weighted average of regional GDP, where the weights decline with transport costs. As a district grows closer to larger, wealthier districts, Island MP$_{dt}$ increases.

We present results in Figure 11 where we plot the coefficients of our instrumented district road roughness effects for the main outcomes and compare these to market potential measure at differing distances. The local road quality has a larger point estimate than the more traditional market potential measures in terms of number of opened firms, log number of workers, and log of rent per room.

6 Conclusion

Even though transportation infrastructure investments typically account for a significant proportion of countries' budgets, little is known about their effects in developing countries, where spatial disparities are particularly pronounced. This paper aims to understand the role road improvement (or deterioration) can play in such countries, not only through looking at possible welfare effects, but also by investigating the different possible mechanisms through which these effects materialize. While much of the previous literature on this topic has focused on the construction of new roads, we add to the literature by evaluating the effects of substantial changes in road quality due to maintenance and upgrading of already existing roads in Indonesia.

Using a novel dataset that documents substantial variation in road quality in Indonesia, and combining this with high quality household panel data that spans years 1990 through 2007, we provide reduced form evidence that road improvements significantly increase welfare, measured either with consumption or income. Additionally, using an annual census of manufacturing firms, we show that these positive welfare effects partially materialize though increased labor market demand, generated by the entry of new firms rather than extended hiring by existing firms. However, we do not see substantial changes in the extensive or intensive margin of labor supply, but instead observe occupational shifts from agriculture into higher paying, newly available manufacturing jobs. In addition, while manufacturing wages typically don't exhibit an upward push, we do observe significant improvements in agricultural profits. This not only implies the wage gap between these two sectors is narrowed, but also confirms the predictions of our stylized model of dual labor markets. The latter shows under what conditions productive amenities, such as transport infrastructure, may translate into positive welfare effects.

The methodological contribution of this paper is in addressing the common concerns of targeting bias and reverse causality by suggesting a new instrument, replicable in many instances. We take advantage of Indonesia's institutional two-step budgeting setup for road funding, where different authorities, such as provinces or districts, are in charge of road quality and funding of different parts of the road network. This allows us to construct a time varying instrument for road quality, which equals total road funding at the provincial or district level. Thus, we identify the effects from the set of roads that get maintained when road budgets allow for it, but which get less maintenance when road budgets are tight or scaled back.

The evidence presented in this paper shows that road improvements alone can present an important stepping stone in economic development through opening up labor market opportunities and decreasing the income gap at the same time. On the flip side, deterioration of roads may have adverse affects in the opposite direction and may bring about important and unanticipated welfare effects that governments should be aware of when cutting transportation budgets.

References

Ahmad, E. and A. M. Mansoor (2002): *Indonesia: managing decentralization*, International Monetary Fund.

Anderson, J. E. and E. Van Wincoop (2004): "Trade Costs," *Journal of Economic Literature*, 42, 691–751.

Asia Foundation (2008): "The Cost of Moving Goods: Road Transportation, Regulations and Charges in Indonesia," Survey report.

Bardhan, P. and C. Udry (1999): *Development Microeconomics*, Oxford: Oxford University Press.

Benjamin, D. (1992): "Household Composition, Labor markets, and Labor demand: Testing for Separation in Agricultural Household Models," *Econometrica*, 60, 287–322.

Bird, R. M. and M. Smart (2001): "Intergovernmental fiscal transfers: Some lessons from international experience," in *March (revision). Paper prepared for Symposium on Intergovernmental Transfers in Asian Countries: Issues and Practices, Asian Tax and Public Policy Program, Hitotsubashi University*.

Blalock, G. and P. J. Gertler (2008): "Welfare Gains from Foreign Direct Investment Through Technology Transfer to Local Suppliers," *Journal of International Economics*, 74, 402–421.

Deaton, A. and J. Muellbauer (1980): "An almost ideal demand system," *The American economic review*, 312–326.

Dickens, W. T. and K. Lang (1985): "A Test of Dual Labor Market Theory," *American Economic Review*, 75, 792–805.

Green, K. (2005): "Decentralization and good governance: The case of Indonesia," .

Jacoby, H. G. (2000): "Access to Markets and the Benefits of Rural Roads," *The Economic Journal*, 110, 713–737.

Levinsohn, J. and A. Petrin (2003): "Estimating Production Functions Using Inputs to Control for Unobservables," *Review of Economic Studies*, 70, 317–342.

Poczter, S., P. Gertler, and A. D. Rothenberg (2014): "Financial Crisis and Productivity Evolution: Evidence from Indonesia," *The World Economy*, 37, 705–731.

Roback, J. (1982): "Wages, Rents, and the Quality of Life," *Journal of Political Economy*, 90, 1257–1278.

Rosen, S. (1979): "Wage-Based Indexes of Urban Quality of Life," in *Current Issues in Urban Economics*, ed. by P. Mieszkowski and M. Straszheim, Johns Hopkins University Press.

Sen, A. K. (1966): "Peasants and Dualism With and Without Surplus Labor," *Journal of Political Economy*, 74, 425–450.

Shah, A., Z. Qureshi, A. Bagchi, B. Binder, and H.-f. Zou (1994): "Intergovernmental fiscal relations in Indonesia: issues and reform options," Tech. rep., China Economics and Management Academy, Central University of Finance and Economics.

Singh, I., L. Squire, and J. Strauss (1986): *Agricultural Household Models: Extensions, Applications, and Policy*, Baltimore: Johns Hopkins University Press.

World Bank (2008): *Spending for Development: Making the Most of Indonesia's New Opportunities*, World Bank.

——— (2012): *Investing in Indonesia's roads : improving efficiency and closing the financing gap.*

bb

Table 1: Road Quality and Budgets

Dep. Var.: Road segment log IRI(t)	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Budget (National Roads)	-0.044			-0.038	-0.047			-0.062
	(0.001)***			(0.001)***	(0.001)***			(0.001)***
Budget (Provincial Roads)		-0.037		-0.016		-0.026		-0.013
		(0.000)***		(0.001)***		(0.000)***		(0.001)***
Budget (District Roads)			-0.015	-0.012			0.006	0.013
			(0.001)***	(0.001)***			(0.001)***	(0.001)***
$\log \mathrm{IRI}_{t-1}$					0.415	0.411	0.294	0.296
					(0.002)***	(0.002)***	(0.005)***	(0.005)***
Years Since Last Upgrade					0.164	0.165	0.137	0.134
					(0.001)***	(0.001)***	(0.001)***	(0.001)***
Years Since Last Upgrade^2					-0.012	-0.012	-0.009	-0.008
					(0.000)***	(0.000)***	(0.000)***	(0.000)***
N	955214	960837	306578	306522	766335	769723	227814	227758
Adjusted R^2	0.078	0.079	0.039	0.051	0.388	0.386	0.259	0.280
F Statistic	2520.469	2734.166	484.572	592.360	11979.469	12074.867	1777.209	1931.070
Road FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

$Budgets_{national\,roads}$: $Mean = 549.89$, $SD = 429.76$
$Budgets_{national\,roads}$: $Mean = 475.43$, $SD = 442.79$
$Budgets_{national\,roads}$: $Mean = 997.45$, $SD = 1502.42$

GDP and # firms at the district level. Robust standard errors in parentheses, clustered at the road segment level. */**/*** denotes significant at the 10% / 5% / 1% levels. This table was constructed using the following .do file: `$do_files/analysis/analysis_roadQuality.do`.

Table 2: Road Budgets and Local Economic Conditions

Dep. Var.: $\log \text{Budget}_t$						
	Province Panel				**District Panel**	
	Nat. roads	Nat. roads	Prov. roads	Prov. roads	Dis.roads	Dis.roads
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$\log \text{GDP}_{t-2}$	0.241		0.251		0.366	
	(0.269)		(0.406)		(0.228)	
$\log \#\text{Firms}_{t-2}$		0.011		-0.004		0.002
		(0.007)		(0.003)		(0.002)
N	241	241	249	249	455	455
Adjusted R^2	0.586	0.589	0.643	0.645	0.441	0.440
Province FE	Yes	Yes	Yes	Yes		
District FE					Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses, clustered at the province or kabupaten level. District budget's top percentile within each year is excluded. */**/*** denotes significant at the 10% / 5% / 1% levels. This table was constructed using the following .do file: `$do_files/analysis/analysis_roadQuality.do`.

Table 3: Travel Times and Road Quality

	FELS	**GMM**	**Statistics**		
	(1)	**(2)**	N	$\overline{Y}$	**KBP**
Panel A: Local Road Quality					
Log Travel t to Nearest City	-0.487 (0.057)***	-0.421 (0.103)***	904	21.272	178.796
Log Travel t to Prov. Capital	-0.447 (0.037)***	-0.652 (0.058)***	904	75.217	178.796
Panel B: Market Potential					
Log Travel t to Nearest City	-0.733 (0.137)***	-0.678 (0.127)***	1032	21.095	453.576
Log Travel t to Prov. Capital	-0.969 (0.092)***	-0.862 (0.058)***	1032	71.353	453.576

We report the results of community-level panel regressions of the dependent variable on road quality or market potential (both in logs). Each cell reports β from a separate regression, with the dependent variable listed in the row heading. All regressions include community and year fixed effects, with controls including logs of current population and non-oil GDRP. Interpretation of results remains unchanged when dependent variables are expressed in levels. Dependent variable means are reported in levels. Robust standard errors, clustered at the community level, are reported in parentheses. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table 4: Road Quality and District-Level Manufacturing Outcomes

	FELS	**GMM**	**Statistics**		
	(1)	**(2)**	N	$\overline{Y}$	**KBP**
Any Firms (0 1)	0.007 (0.017)	0.273 (0.108)**	3381	0.956	57.173
Log Number of Opened Firms	0.035 (0.058)	1.582 (0.285)***	3381	1.218	57.173
Log Number of Closed Firms	-0.078 (0.069)	0.061 (0.293)	3184	1.171	65.882
Percent Δ Number of Firms	-0.003 (0.020)	0.356 (0.124)***	3337	-0.032	59.892
Log Output	0.296 (0.235)	3.860 (1.366)***	3381	14.612	57.173
Log Value Added	0.256 (0.216)	3.439 (1.262)***	3381	13.510	57.173
Log Investment	-0.394 (0.369)	3.350 (1.460)**	2388	11.356	80.940
Log Export Share	-0.018 (0.020)	0.018 (0.047)	3232	0.119	59.808
Log Avg TFP	0.078 (0.075)	0.793 (0.336)**	3043	8.250	69.181
Log Number of Workers	-0.020 (0.099)	0.998 (0.436)**	3381	4.379	57.173
Log Wage Rate	0.040 (0.036)	-0.003 (0.158)	3198	7.687	59.113
Log Output per Worker	0.296 (0.086)***	0.908 (0.292)***	3232	10.458	59.808
Log Value Added per Worker	0.237 (0.091)***	0.738 (0.275)***	3232	9.305	59.808

We report the results of district-level panel regressions of the dependent variable on island market potential. Each cell reports β from a separate regression, with the dependent variable listed in the row heading. All regressions include district and year fixed effects, with controls that include logs of current population and non-oil GDRP. Robust standard errors, clustered at the district level, are reported in parentheses. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table 5: Road Quality and Firm-Level Manufacturing Outcomes

	FELS	GMM	Regression Stats		
	(1)	(2)	N	$\overline{Y}$	KBP
Log Output	-0.032	-0.140	278441	13.959	12.255
	(0.041)	(0.189)			
Log Value Added	-0.055	-0.100	278368	12.880	12.245
	(0.047)	(0.212)			
Log Total Labor	-0.007	-0.101	278539	4.111	12.227
	(0.012)	(0.063)			
Log Wage Rate	-0.028	-0.227	248494	7.731	10.730
	(0.034)	(0.159)			
Log Investment	0.279	-0.342	178655	5.234	38.127
	(0.374)	(0.796)			
Exporter (1 0)	0.003	0.045	278709	0.128	12.226
	(0.012)	(0.043)			
Log Output per Worker	-0.023	-0.044	278284	9.848	12.257
	(0.039)	(0.169)			
Log Value Added per Worker	-0.048	-0.003	278217	8.768	12.247
	(0.045)	(0.203)			
Log Total Factor Productivity	0.005	-0.084	143558	7.834	16.490
	(0.038)	(0.163)			
Year FE	Yes	Yes			
District FE	Yes	Yes			
Firm FE	Yes	Yes			

We report the results of firm-level panel regressions of the dependent variable on road roughness. Each cell reports β from a separate regression, with the dependent variable listed in the row heading. All regressions include firm and year fixed effects. Controls include logs of current population and non-oil GDRP. Robust standard errors, clustered at the district level, are reported in parentheses. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table 6: Road Quality and Individual-Level Panel Outcomes

	FELS	GMM	Regression Stats		
	(1)	**(2)**	N	$\overline{Y}$	KBP
Any Employment (0 1)?	-0.022	0.000	36851.000	0.701	32.000
	(0.020)	(0.040)	(.)	(.)	(.)
Log Total Hours Worked	-0.012	-0.038	23290.000	5.150	31.237
	(0.037)	(0.080)	(.)	(.)	(.)
Log Total Earnings	0.128	0.388	16357.000	11.446	27.528
	(0.071)*	(0.157)**	(.)	(.)	(.)
Agriculture ... Any Employment (0 1)?	-0.065	-0.085	23293.000	0.418	31.232
	(0.018)***	(0.043)**	(.)	(.)	(.)
... Log Total Hours Worked	-0.163	-0.004	23499.000	1.834	30.918
	(0.128)	(0.267)	(.)	(.)	(.)
... Log Earnings	1.182	2.484	5308.000	7.824	13.431
	(0.778)	(1.473)*	(.)	(.)	(.)
Manufacturing ... Any Employment (0 1)?	0.080	0.100	23293.000	0.290	31.232
	(0.023)***	(0.050)**	(.)	(.)	(.)
... Log Total Hours Worked	0.433	0.849	23839.000	1.466	30.933
	(0.114)***	(0.247)***	(.)	(.)	(.)
... Log Earnings	-0.078	0.298	4336.000	11.228	15.721
	(0.191)	(0.564)	(.)	(.)	(.)
Sales and Services ... Any Employment (0 1)?	-0.043	-0.160	23293.000	0.313	31.232
	(0.021)**	(0.043)***	(.)	(.)	(.)
... Log Total Hours Worked	-0.276	-0.840	23531.000	1.519	31.290
	(0.107)***	(0.209)***	(.)	(.)	(.)
... Log Earnings	0.172	0.127	4174.000	11.047	22.717
	(0.224)	(0.481)	(.)	(.)	(.)
Other ... Any Employment (0 1)?	0.018	0.034	23293.000	0.114	31.232
	(0.012)	(0.023)	(.)	(.)	(.)
... Log Total Hours Worked	0.699	3.313	23326.000	17.246	31.299
	(2.638)	(4.920)	(.)	(.)	(.)
... Log Earnings	0.067	0.056	69582.000	0.542	35.385
	(0.059)	(0.112)	(.)	(.)	(.)
Other (Informal) ... Any Employment (0 1)?	-0.048	-0.119	23293.000	0.225	31.232
	(0.018)***	(0.036)***	(.)	(.)	(.)
... Log Total Hours Worked	-0.370	-0.646	23293.000	1.252	31.232
	(0.194)*	(0.380)*	(.)	(.)	(.)
... Log Earnings	0.797	1.296	3757.000	8.643	26.552
	(0.618)	(1.050)	(.)	(.)	(.)
Other (Formal) ... Any Employment (0 1)?	0.026	0.001	23293.000	0.190	31.232
	(0.015)*	(0.029)	(.)	(.)	(.)
... Log Total Hours Worked	0.869	0.728	23293.000	1.158	31.232
	(0.353)**	(0.662)	(.)	(.)	(.)
... Log Earnings	-0.969	-2.438	3275.000	4.584	23.271
	(0.557)*	(1.217)**	(.)	(.)	(.)
Individual FE	Yes	Yes			
Year FE	Yes	Yes			

We report the results of individual-level panel regressions with individual and survey-wave fixed effects. Each cell reports estimates of β from a separate regression, with the dependent variable listed in the row heading. Controls include: district GDP, individual age, education, household size, and month of survey indicators. Total hours worked is defined only if the individual reported working. Earnings regressions also include hours worked (by sector) as a control. Robust standard errors in parentheses, clustered at the (initial) village level. */**/*** denotes significant at the 10% / 5% / 1% levels. Full results, including results restricted to the sample of non-moving individuals, can be found in Appendix Tables.

Table 7: Road Quality and Household-Level Panel Outcomes

	FELS	GMM	Regression Stats		
	(1)	**(2)**	N	$\overline{Y}$	KBP
Log of Per-Capita Consumption Expenditures	0.140	0.182	23129	11.064	39.372
	(0.040)***	(0.093)*			
Log of Land Value	0.283	0.969	7325	14.806	18.188
	(0.162)*	(0.322)***			
Log of Rent Per Room	0.199	0.726	19242	8.316	38.708
	(0.063)***	(0.135)***			
Household FE	Yes	Yes			
Year FE	Yes	Yes			

We report the results of household-level panel regressions with household and survey-wave fixed effects. Each cell reports estimates of β from a separate regression, with the dependent variable listed in the row heading. Controls include: current district population, district GDRP, survey wave indicators, survey month indicators, and controls for household size. For the land value regressions, we also include controls for the number of rooms, whether the house has electricity, piped water, its own toilet, indicators for types of floor (cement, dirt), walls (masonry), and a tiled roof. For the log rent regression, we use the same additional controls but also add an indicator for whether the rent observation is actual rent, as opposed to being estimated. Robust standard errors in parentheses, clustered at the (initial) village level. */**/*** denotes significant at the 10% / 5% / 1% levels. Full results, including results restricted to the sample of non-moving households, can be found in Appendix Tables.

Table 8: Road Quality and District-Level Migration Outcomes

	FELS	GMM	Regression Stats		
	(1)	**(2)**	N	$\overline{Y}$	KBP
Percent Δ Population (2000-1990)	0.033	-0.012	198.000	0.137	9.527
	(0.058)	(0.133)	(.)	(.)	(.)
Log Share of Recent Migrants	1.013	1.080	198.000	-3.260	6.005
	(0.220)***	(0.460)**	(.)	(.)	(.)
Log Total Recent Migrants	0.868	0.993	198.000	10.014	6.005
	(0.255)***	(0.525)*	(.)	(.)	(.)
Province FE	Yes	Yes			

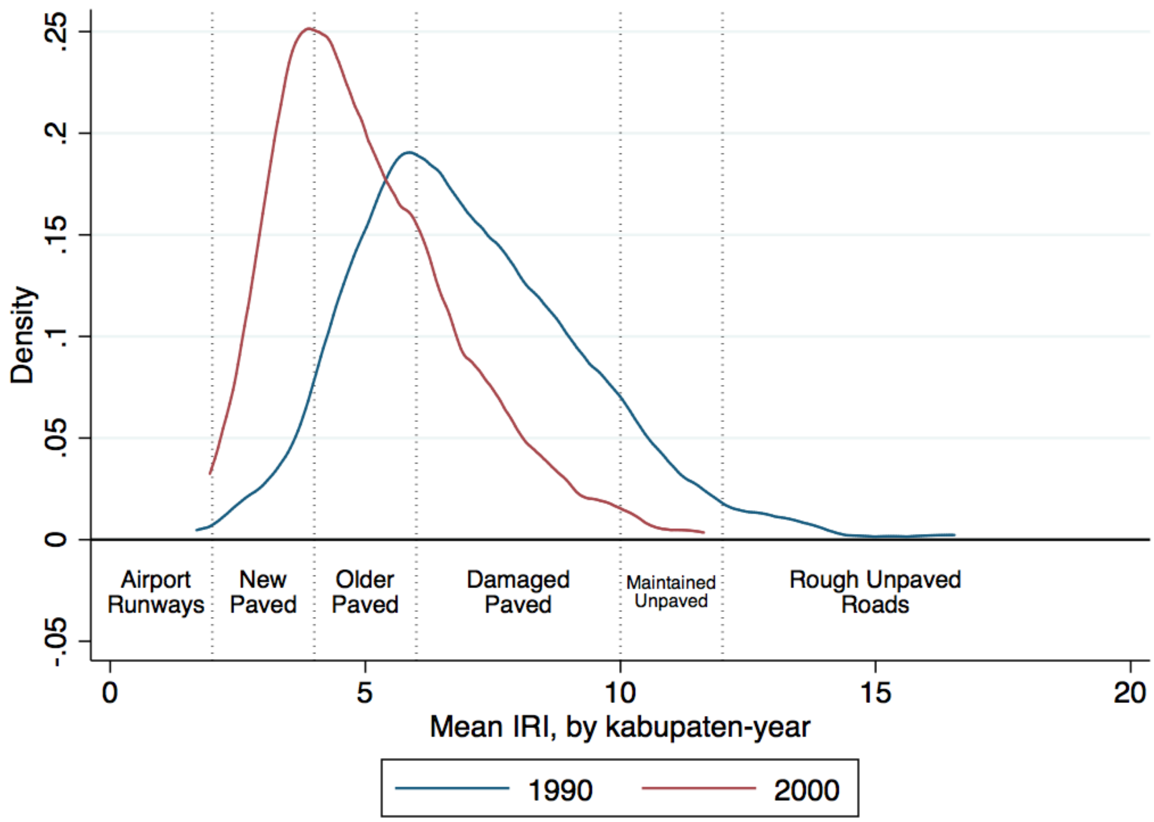
We report the results of cross-sectional regressions of the dependent variable on changes in road roughness. Each cell reports estimates of β from a separate regression, with the dependent variable listed in the row heading. For the migration regressions, controls include logs of 1990 population and 1990 non-oil GDRP. Robust standard errors reported in parentheses. */**/*** denotes significant at the 10% / 5% / 1% levels.

Table 9: Prices and Road Quality

	FELS	GMM	Statistics		
	(1)	**(2)**	N	$\overline{Y}$	**KBP**
Panel A: Local Road Quality					
Log Factory Wage	-0.087	-0.169	226	3842.123	31.122
	(0.175)	(0.359)			
Log Farm Wage	0.031	0.092	342	3770.043	89.887
	(0.111)	(0.192)			
Log Food Price	-0.109	0.033	914.000	146.450	184.993
	(0.079)	(0.149)	.	.	.
Log Tradables Price	0.004	0.228	914.000	135.623	184.993
	(0.087)	(0.147)	.	.	.
Log Perishables Price	-0.314	-0.679	914.000	76.494	184.993
	(0.091)***	(0.176)***	.	.	.
Panel B: Market Potential					
Log Factory Wage	0.111	-0.148	258	3894.816	107.033
	(0.213)	(0.234)			
Log Farm Wage	-0.122	-0.092	374	3908.646	177.180
	(0.153)	(0.188)			
Log Food Price	-0.092	0.127	1045.000	147.620	439.083
	(0.093)	(0.118)	.	.	.
Log Tradables Price	0.137	0.210	1045.000	135.220	439.083
	(0.117)	(0.136)	.	.	.
Log Perishables Price	-0.444	-0.587	1045.000	76.639	439.083
	(0.109)***	(0.117)***	.	.	.

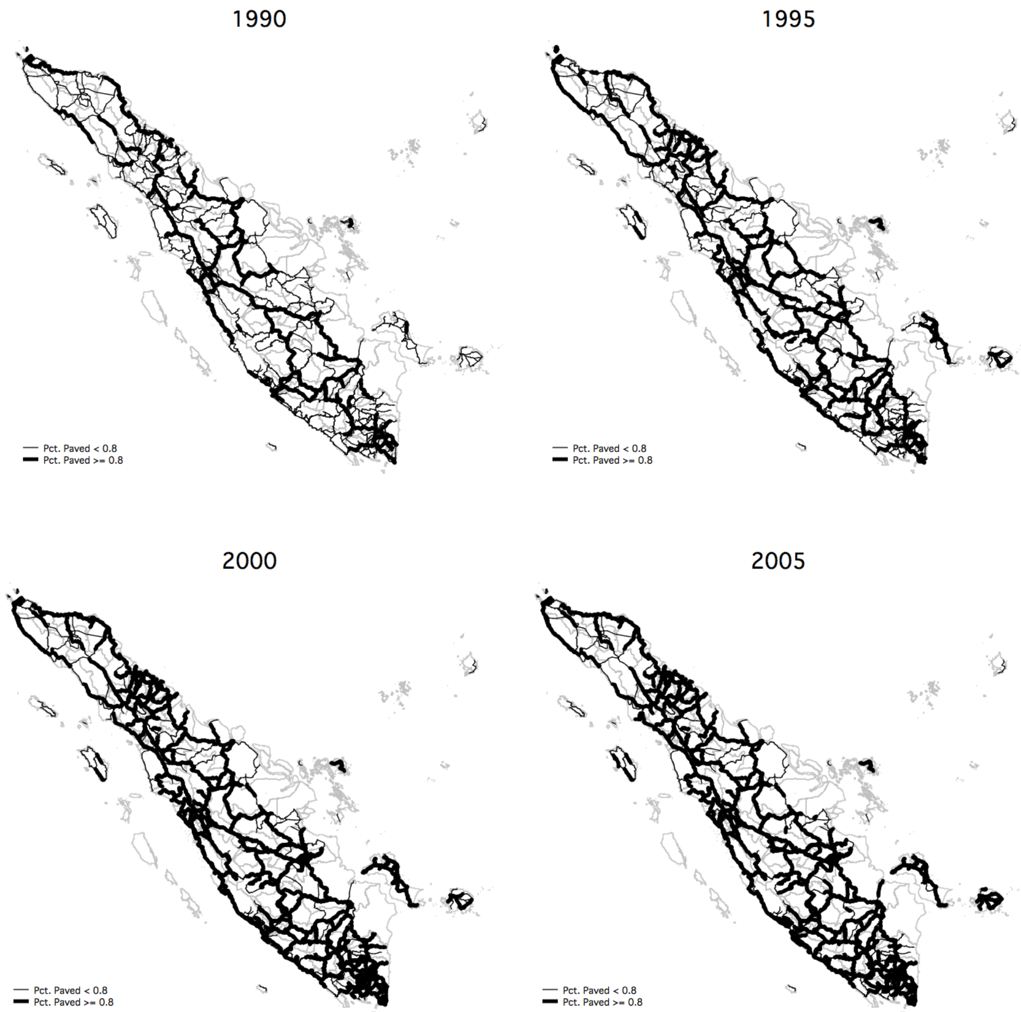
We report the results of community-level panel regressions of the dependent variable on local road quality or market potential (both in logs). Each cell reports β from a separate regression, with the dependent variable listed in the row heading. Log(Farm Wage) is not available in 1993. Dependent variable means are reported in levels. Robust standard errors, clustered at the community level, are reported in parentheses. */**/*** denotes significant at the 10% / 5% / 1% levels.

Figure 1: Changes in the Distribution of Road Roughness



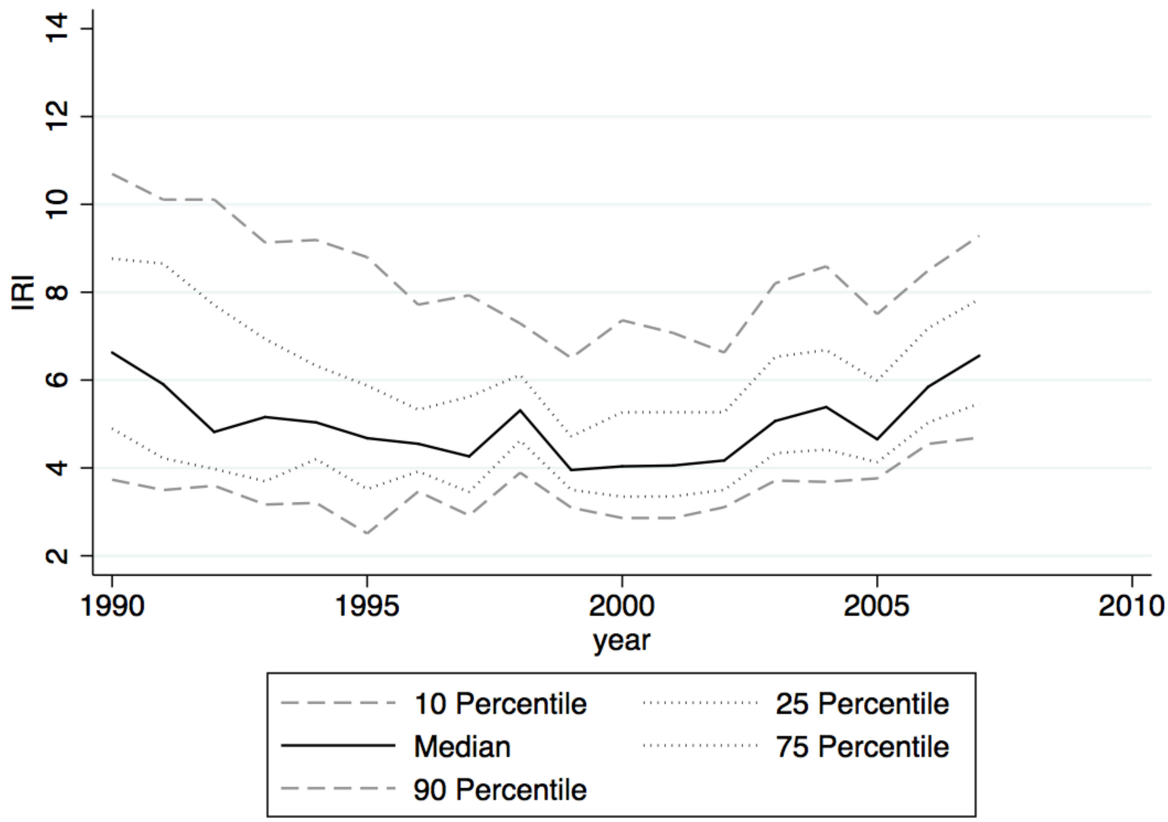
Note: Authors' calculations.

Figure 2: Road Roughness - Sumatra



Note: Authors' calculations.

Figure 3: Changes in Roughness

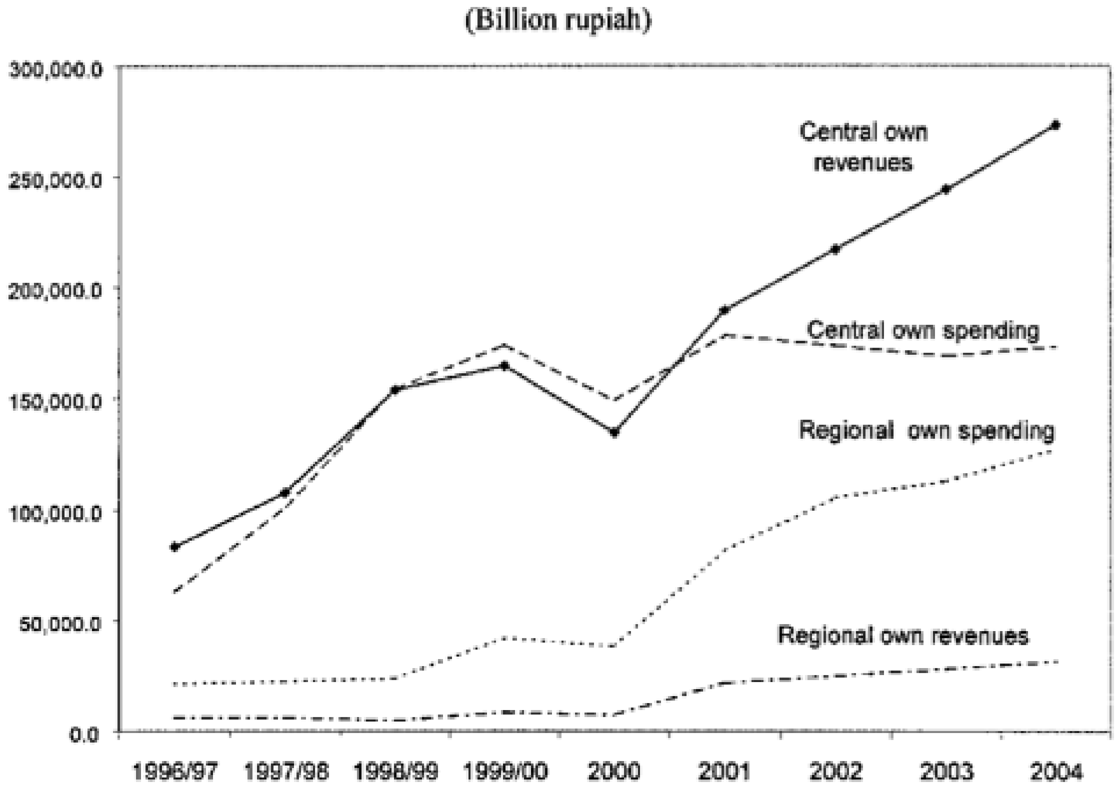


Note: Authors' calculations.

Figure 4: IFLS Villages

Note: Authors' calculations.

Figure 5: Impact of Decentralization in Indonesia



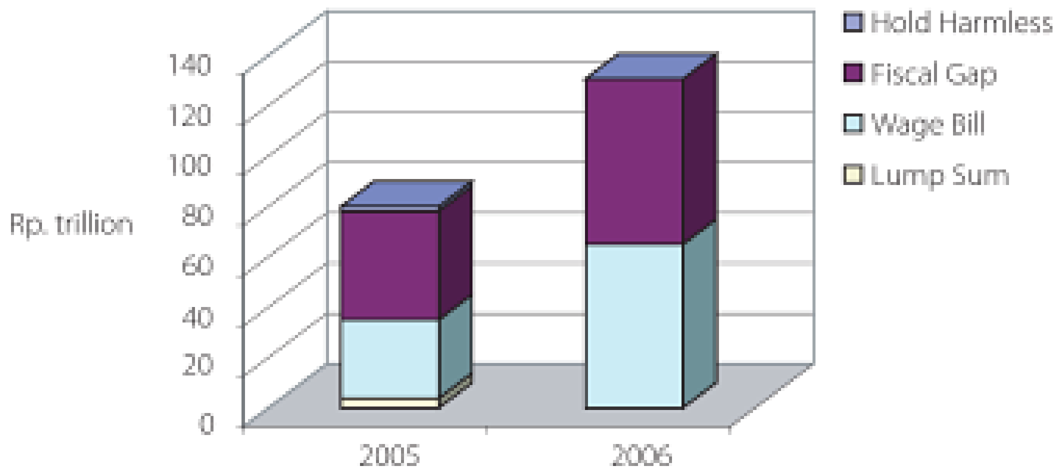
Note: In billion rupiah. (Ahmad and Mansoor, 2002).

Figure 6: Allocation Criteria for District Road Improvement Grant

1989/90	1990/91	1991/92	1992/93
CRITERIA	CRITERIA	CRITERIA	CRITERIA
1. Length of road (20%) 2. Unstable & critical road (52%) 3. Area of irrigation (15%) 4. Increase of actual regional own-source receipts (PAD)(7%) 5. Actual own-source revenues compared to planned(6%) 6. Unit price correction (Ditjen Cipta Karya)	1. Length of road (15%) 2. Road condition (60%) 3. GRDP (15%) 4. Road density (10%) 5. Unit price correction	1. Length of road 2. % of good road a. Kab < 28.3% good road b. 55% > Kab > 28.3% good road 3. Road density a. Kab < 28km/1000km2 b. 100km/1000km2 > Kab > 28km/1000km2 4. Performance Kabupaten needs according to (a) and (b) greater than 60km, take 60km 5. Unit price correction	1. Length of road 2. % of good road a. Kab < 17.68% good road b. 55% > Kab > 17.68% 3. Road density a. Kab < 40.29km/1000km2 b. 100km/1000km2 kab > 40.29km/1000km2 4. Performance Kabupaten needs according to (a) and (b) greater than 60km, take 60 km 5. Unit price correction

Note: (Bird and Smart, 2001).

Figure 7: Changes in DAU composition over time



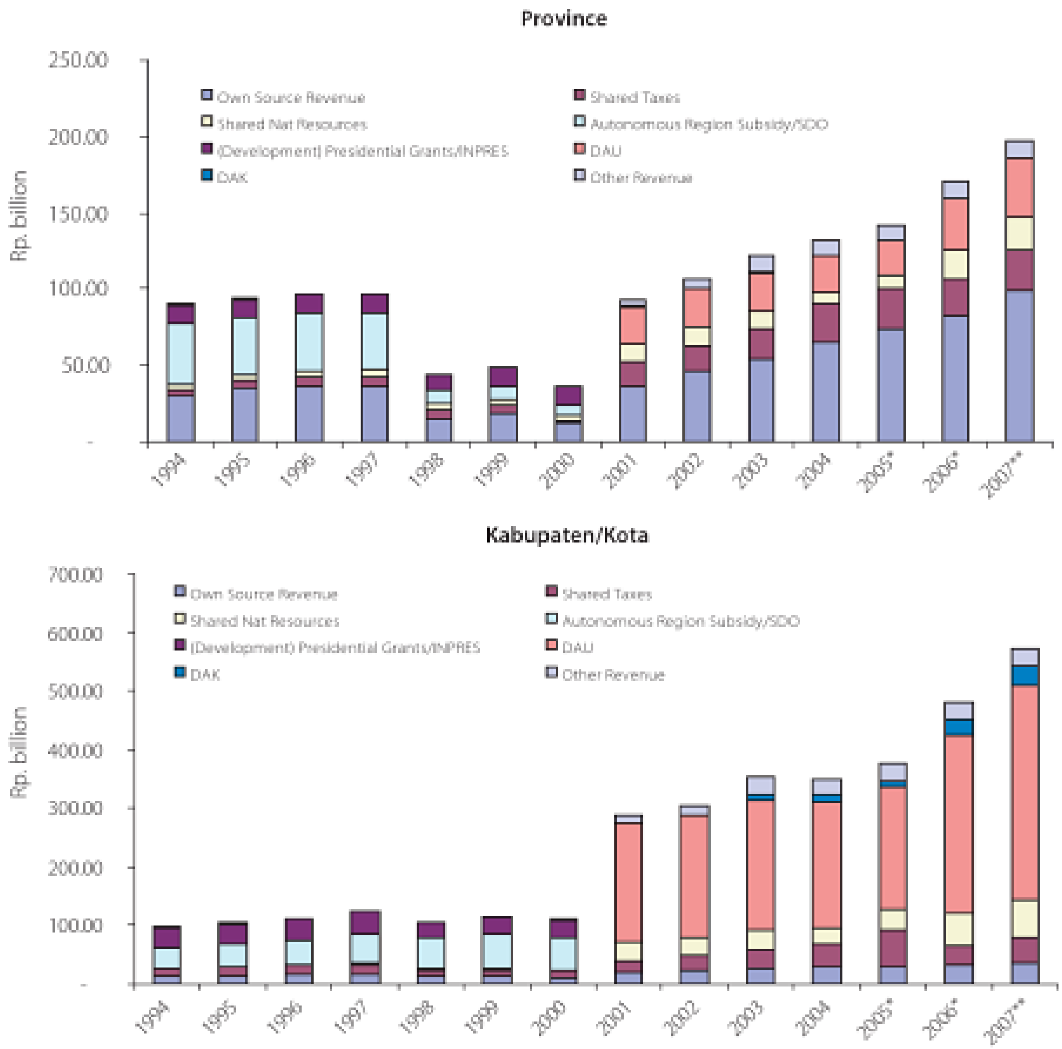
Note: World Bank staff calculation. (World Bank, 2008).

Figure 8: The evolution of technical criteria in the DAK formula for roads and their respective weights

No.	Technical criteria	Description	2008	2009	2010	2011
1	Length of road	Length of road which is legally acknowledge through the decree of the head of local government	30%	25%	25%	25%
2	Road condition	Length of road with non-stable condition	30%	40%	35%	25%
3	Good road performance		20%			
4	Accessibility	Defined by the length of road divided by total area			20%	10%
5	Mobility	Length of road per 1000 population in the province/kabupaten			20%	10%
6	Ownership/concern by LG	Determined by the percentage of original APBD allocated to the road sector		20%		10%
7	Reporting	Consistency in submitting of quarterly report, physical progress, financial progress	20%	15%		20%

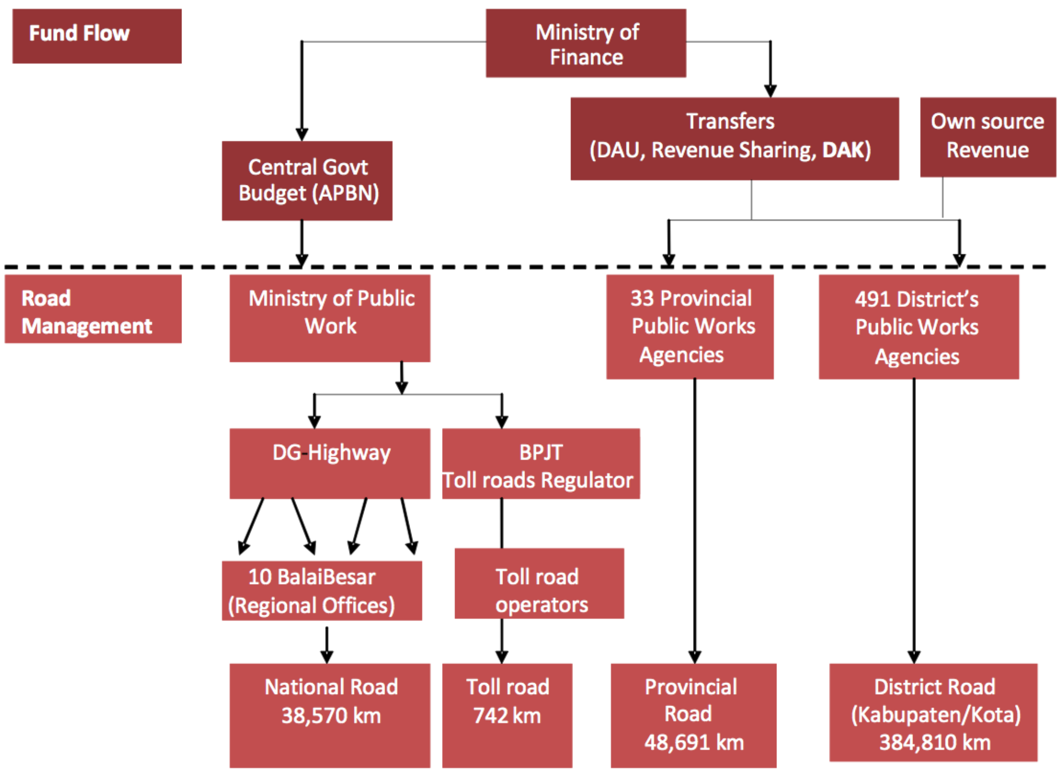
Note: (World Bank, 2012).

Figure 9: Sub-national revenue over time



Note: World Bank staff calculation. (World Bank, 2008).

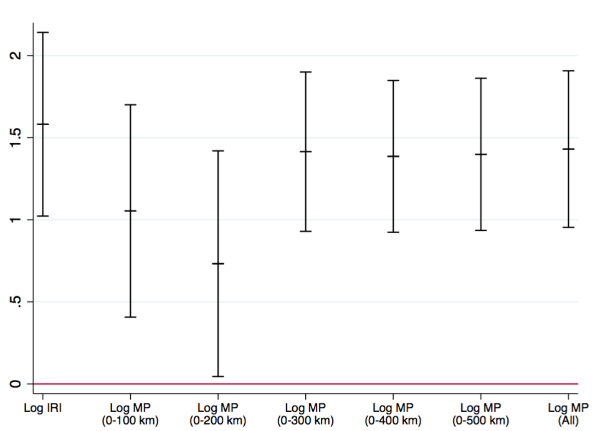
Figure 10: Institutional Arrangements for the Road Sector in Indonesia



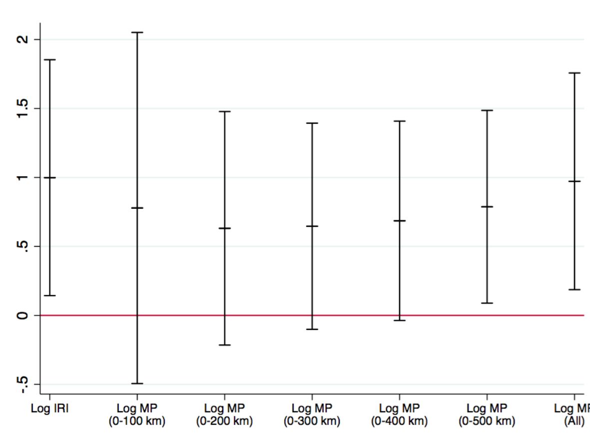
Source: (World Bank, 2012).

Figure 11: Coefficients Plots

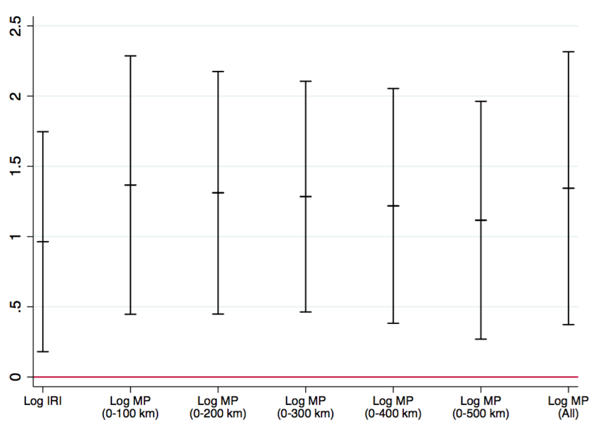
(A) Log # of Opened Firms, District-Year



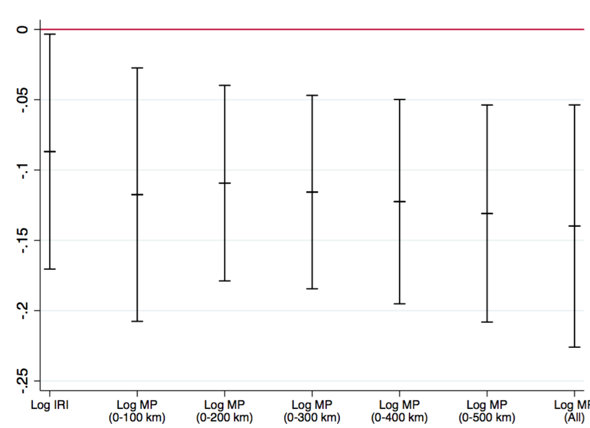
(D) Log # of Workers, District-Year



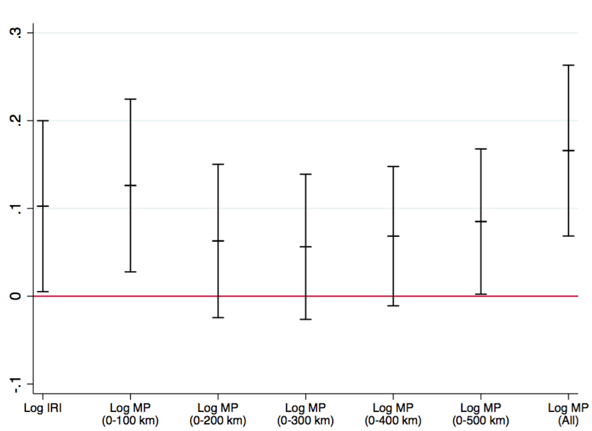
(B) Log Total Earnings, Individual Panel



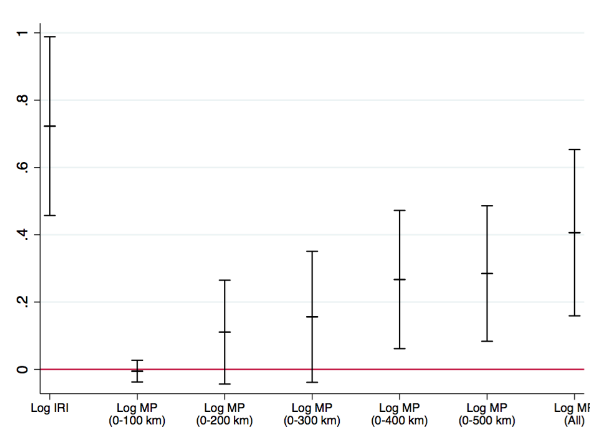
(E) Any Employment in Agriculture? (0 1), Individual Panel



(C) Any Employment in Manufacturing? (0 1), Individual Panel



(F) Log of Rent Per Room, HH Panel



Note: We plot the GMM coefficient estimates and 95% confidence intervals.