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

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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.

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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.

[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. Donaldson, 2010).

The paper proceeds as follows: In section 2 we provide a theoretical framework, followed by the section 3, which lays out the main datasets used. Section 4 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:

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

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

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

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:

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

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:

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

[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 Data

3.1 Road Quality Data

One of the key problems when evaluating the impacts of changes in transport infrastructure is the scarcity of data on road quality.[4] In this paper, we are able to use a very rich longitudinal dataset of road roughness from Indonesia that provides us with a novel and previously unused measure of road quality. Every year, the Indonesian Department of Public Works (*Departemen Pekerjaan Umum*, or DPU) conducts a high resolution data collection effort to monitor pavement deterioration as part of Indonesia's Integrated Road Management System (IRMS). These measurements are conducted annually by a team of surveyors who collect information on surface type, width of road segments and road roughness. The dataset is extremely detailed, with more than 1.2 million kilometer-post-interval-year observations, merged to the kilometer-post interval data to shapefiles of the road networks. This provides us with an annual panel of road quality measures along the whole network of Indonesian highways for the years 1990-2007.

[4]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 (Donaldson (2010), Atkin et al 2014.)

The measure of road quality we use in the paper is based on the roughness of the road. Road roughness is measured using the international roughness index (IRI), a widely accepted measure of road quality in civil engineering, developed by the World Bank in the 1980s. It 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 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 result in increased fuel consumption. In consequence, road roughness is directly related to transport costs and can be thought of as a measure of road quality as we do throughout this paper.

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 roughness measure is defined as:

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

where IRI_{rdt} denotes the road roughness of road section r in district d at time t. In our empirical analysis, the regressor of interest is *road quality* simply defined as the negative of $log(\text{Roughness}_{dt})$.

Figure 1 shows a significant leftward shift in the distribution of Roughness_{dt} across districts between 1990 and 2007. Similarly, Figure 2 documents substantial spatial variation in road improvements over time. For instance, Sulawesi's road network went from 84 percent of unpaved roads in 1990 to only 46 unpaved roads only a decade later. After the year 2000, however, Indonesia's roads started to deteriorate, which is evident in Figure 3. Similar trends apply to Sumatra's and Java's highway network.

Although we focus on this measure of road quality for the analysis, it is worth mentioning that the results are robust to using a different measure which is *roughness-induced travel times to provincial capitals*. This variable is created using the mapping proposed by Yu et al. (2006) in which the maximum speed that one can travel over a road with a given roughness level while maintaining a constant level of ride quality is provided. Given this roughness-induced speed limit, one can calculate travel times along network arcs and to compute the time-minimizing path between different regions (Dijkstra, 1959).

3.2 Census of Manufacturing Firms

Our primary data source for firm-level outcomes and analysis 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.[5]

3.3 Indonesian Family Life Survey

Our data source for the individual and household outcome level analysis, such as individual employment status (working or not), hours worked, earnings, and household consumption per capita, 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 in more than 300 villages (*desa*), which are located in 13 of Indonesia's 27 provinces. 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.

The IFLS contains detailed modules not only of labor market activity or household level consumption, but also data on other demographic characteristics, including age, gender, and educational attainment. Figure 4 shows the locations of IFLS villages used throughout our analysis. The panel is notable for its time span, allowing us to implement what is to our knowledge the first panel data in which we can track the same households facing different road infrastructure conditions over almost twenty years.

4 Empirical Strategy

4.1 Roads in Indonesia

Throughout the first half of the XXth century, Indonesia was a Dutch colony managed through the Dutch East India Company. During this period, the Dutch colonists built and maintained a modern road network. The second World War and the Japanese occupation were followed by independence and the emergence of Suharto, who assumed power in 1967. For Suharto, rehabilitation of roads, which had been left to deteriorate since the war, became a top priority of his five-year development plans, called Repelitas (Rencana Pembangunan Lima Tahun, or *Repelita*).

However, the oil price shocks and the subsequent collapse of state oil revenues in the late 1970s led to spending on road infrastructure which stagnated until the early 1990s. Then, in the 1990's

[5]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).

road investment experienced an upswing in which the budget share allocated to road improvements increased substantially. Between Repelita IV (1984 - 1989) and Repelita V (1989 - 1994) the total budget for road improvements almost doubled from $2.1 to around $3.9 billion.[6] During Repelita V, transportation constituted the single largest item of the development budget. However, after the fall of Suharto, followed by the Asian financial crisis in 1997/1998, infrastructure investment fell dramatically, and has experienced a recovery ever since (World Bank, 2012). The recent Indonesian experience hence provides with substantial variation over time in road maintenance expenditures. An additional advantage of the Indonesian setting is that the lion's share of road investment goes toward maintaining and improving the existing road network, for example by upgrading dirt roads to asphalted ones.

4.2 Government Revenues and Resource Distribution

Indonesia's government revenues are highly centralized. The national government revenues are composed - in approximately equal shares - of the tax income, the value added tax and natural resource revenues. These national resources are then shared among the national government, the provinces and the districts.

The sub-national governments are highly dependent on these centralized transfers. According to the the World Bank (2005), only 15% of provincial revenues are own sourced, and of these, the majority are accounted for by health services charges.

A similar situation holds for districts. According to UNDP (2009) 70% of district revenues are from the general allocation fund (DAU), while 13-25% come from national natural resources revenue sharing and 6% from targeted transfers (DAK). Importantly, the natural resource revenue sharing is equalized among producing and non-producing districts. Only 6% of revenues in districts are from own resources, again mostly derived from health services charges (Green, 2005; World Bank, 2012). Indonesia's fiscal policy is not unusual for a developing country. National governments have the expertise and know-how to collect taxes, and decentralization has mainly meant a generous transfer of resources to subnational governments.

In terms of government attributions, the provision of road infrastructure has been to a large degree decentralized since the early 1990s. This led to consolidation of three independent sets of road authorities: national (managed by 33 provincial offices), provincial (33) and district (more than 400), each in charge to its own set of road segments.

This setup can be thought of as following a two-stage budgeting procedure (Deaton and Muellbauer, 1980). In the first stage, the government distributes nationally collected revenue to the subnational units, and these then allocate funds to their road maintenance agencies. Grants are allocated according to national formulas that utilize differently weighted objective criteria on which local governments have little control (such as area, density, population) and hence can be

[6] These figures are expressed in 2000 U.S. dollars.

considered orthogonal to changes in local economic developments. Allocation formulas are mostly designed to help equalizing the fiscal capacities of sub-national governments, regional development, and to decrease poverty rates (Bird and Smart, 2001).

Criteria for distribution formulas and especially their weights have moved over time. For example, before 1998, the distribution criteria for provincial and district development grants consisted of a fixed, lump-sum grant and a variable part, depending on local area and population (for provinces) and length of the road network. Figure 5 shows the structure and changes of weights before the 2000s.

After 2000, the main revenue sources for sub-national road development are broadly divided into two groups: first, earmarked financing and second, non-earmarked financing. Earmarked financing consists of DAK for roads (Daka Alokasi Khusus, or Special Allocation Grant). Non-earmarked financing for roads comes mainly from the general funds (DAU). DAU is distributed based on a national formula. The national formula is based on population, area, GDP per capita, and human development index. Weights for each criteria or their implementation change every couple of years either for DAK (see Figure 7) or DAU (e.g. see Figure 8), mostly through changes in decentralization laws (World Bank, 2008).[7] For more details on revenue sources over time see Figure 9. What is important about this fiscal arrangement is that it induces an orthogonality between fiscal resources in subnational units (the main determinant of road maintenance funds) and local economic conditions. Second, the abrupt changes in budgets for road funding authorities generate time variation maintenance budgets.[8]

In the second stage, sub-national governments observe their allocated funds, and endogenously select which roads to upgrade in the sense of potentially being correlated to local economic conditions. First, the extent to which local grants and revenues are allocated for road improvements is at the discretion of provincial and district governments. One of the official criteria for the inter-governmental 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). This is true especially since the mid 1990s, when most of the government expenditure functions were devolved to provinces and districts(Green, 2005; World Bank, 2008).[9] What is relevant for identification is that this stage is independent from the first one.

[7]For example, until 2005, the basic allocation component of DAU consisted of a lump sum and civil service wage bill covering a portion of wage bill and used the poverty index as one of the "fiscal gap" criteria. Since 2006, however, the basic allocation component of DAU covers the full wage bill, whereas weights for the "fiscal gap" criteria, such as own revenue, shared tax revenue and natural resource revenue, changed. Also, human development index and GDP replaced the poverty index used prior to 2006.

[8]For more details on the institutional arrangement for the road sector in Indonesia, see Figure 6.

[9]Sub-national governments are now managing over 35 percent of total public expenditures, compared to 24 percent in the mid 1990s. Figure 10 shows a significant and relatively constant gap between revenues and expenditures at a national and regional level over time.

4.3 Road Budgets

We have no direct data on the amounts allocated to roads, and in any case, these may not be so informative about actual road improvements given corruption and monitoring issues common to developing countries (Olken, 2007). However, we can build an objective measure of road investments from the road roughness information we do have. 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 an indicator for whether or not road r was upgraded between $t-1$ and t:

$$U_{rt} = \mathbb{1}\{\text{IRI}_{r,t} < \text{IRI}_{r,t-1}\}$$

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

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

where d_r denotes the length of segment r and $R(A)$ denotes the set of roads in 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. This is simply the sum of kilometers being improved between t and $t-1$ by road authority A weighted by the change in IRI of each road segment - so that larger changes in roughness represent a larger budget spent improving the road. If costs of upgrading are approximately linear, then weighting the upgrading indicator by the change in roughness should be a good proxy for the total amount of expenditures on roads by the authority.

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, $p(d)$. So 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.

4.4 Empirical Strategy

Our equation of interest takes the following form:

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

where d indexes districts and y_{dt} is the dependent variable observed for district d at time t. The variable $\log(\text{Road Quality})_{dt}$ 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 correlated with changes in road quality and outcomes of interest through district and time fixed effects, or α_d and α_t respectively. Standard errors are clustered at the district level.

If road authorities routinely allocated funds for road upgrades to locations that were historically poor (or wealthy), that is, based on time invariant characteristics, then the fixed effects equation above would be sufficient to remove the targeting bias from our parameter estimates.

However, one major concern in estimating equation (11) directly is that the estimates could be confounded by the fact that areas receiving improvements were selected by policymakers for economic growth or expected growth reasons, creating endogeneity bias. Hence, the worry of targeting bias remains whenever it is time varying. A second source of concern is that if substantial economic activity causes roads to deteriorate faster due to their extensive use, this could generate attenuating bias.

To address these concerns, we use a IV-GMM approach as our preferred specification, using road maintenance budgets in the province (for national, provincial roads) as instruments for road quality in district d. In the budget instruments case, the budget for district d is calculated using all the other districts in the province except for d (a leave out sum).

Note that budgets vary annually for each authority according to the distribution of funds rules explained previously. However, the share of roads in in any given district allocated to a particular road authority is predetermined. Districts vary widely in the share of national, provincial and district road shares. So if a year is exceptionally good for national roads, this will generate an exogenous improvement in districts with a larger share of national roads but not in those with larger shares of provincial roads.

Columns 1, 2, and 3 in Table 1 show that budgets for all types of roads in a district are indeed strongly correlated to road budgets. Columns 4, 5, and 6 in the same table show that budgets have a large and significant effect on road quality. The negative sign of the coefficient confirms that whenever the road authorities have a more generous budget, any given road segment in the district for that authority is more likely to be of better quality (less rough). These results confirm the relevance of our instrument for road quality.

We can also provide evidence that the instruments are indeed exogenous by regressing current changes in road quality against lagged economic activity. To test this, we can regress the road budget of provincial road authorities against the lagged province GDP and lagged number of firms (see Table 2 columns 1 and 2, respectively). Columns 3 and 4 show an analogous exercise for district road budgets against district GDP and district number of firms. In all cases we cannot reject that the coefficients on economic conditions are uncorrelated to the road budget. These results increase our confidence that the exclusion restriction of our proposed instrument at the district level is satisfied and the financing of the first stage indeed functions as described above.

Since we are identifying from a local average treatment effect, it makes sense to discuss briefly where identification is coming from. Local road authorities typically have priority rankings for roads under their purview. For example, they may place a high priority for roads around the largest city in the province, or the highway that connects to the provincial capital. These high priority roads are typically always well maintained. On the other hand there are roads that only get upgraded in years of generous budgets, and finally, roads that rarely see improvements even in good budget years because they are such low priority. Our identification of effects comes from road segments that tend to be upgraded in good budget years. Because the set of roads allocated to each authority is predetermined and does not change over time, the interaction of the road share under different authorities in a district (time invariant and exogenous) and the time varying road budgets by road authority mean that this interaction is likely to be exogenous for road quality in a district and relevant for road quality.

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 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 instrumental variables ones in column 2.

The top panel describes the effects of road quality on the 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 (rows 2) rather than reduced closure of firms (row 3).

The second panel shows that district level log manufacturing output goes up 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.[10]

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 see in the household level outcomes that manufacturing jobs are more desirable than those in other sectors and hence that workers are 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:

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

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

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.[11] 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.[12] This Table together 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 not pre-existing firms.

5.3 Road Quality and Individual-Level Outcomes

We next turn to effects of roads on individual level labor market outcomes from 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. 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 worker earnings. Specifically, the bottom five panels decompose the likelihood of being occupied in any given sector. The first thing to notice is that improved roads lead to a substantial reduction in the likelihood of being occupied 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 being employed 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, because it 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

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

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

from the agricultural and services sectors, which are 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, and hours worked are only defined for people who are working) show that conditional on working on the sector of employment, road 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 gap between working in 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.[13]

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.[14] 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).

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.

[13]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:

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

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.

[14]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 $A = N, p(d)$.

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:

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

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 of course 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

The trade literature argues lower transportation costs should be reflected in prices (Donaldson, forthcoming). In this paper we argue that the effect of local road quality is also a productive input, meaning that effects can come from quantities being produced and consumed without necessarily being reflected in price changes. 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.

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.

DIJKSTRA, E. W. (1959): "A Note on Two Problems in Connexion with Graphs," *Numerische Mathematik*, 1, 269–271.

DONALDSON, D. (2010): "Railroads of the Raj: Estimating the Impact of Transportation Infrastructure," Working Paper.

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.*

Yu, J., E. Chou, and J. Yau (2006): "Development of Speed-Related Ride Quality Thresholds using International Roughness Index," *Transportation Research Record*, 1974, 47–53.

Table 1: Road Quality and Budgets

Dep. Var.: Road segment log IRI(t)	(1)	(2)	(3)	(4)	(5)	(6)
Budget (National Roads)	-0.044			-0.047		
	(0.001)***			(0.001)***		
Budget (Provincial Roads)		-0.037			-0.026	
		(0.000)***			(0.000)***	
Budget (District Roads)			-0.015			0.006
			(0.001)***			(0.001)***
$\log \text{IRI}_{t-1}$				0.415	0.411	0.294
				(0.002)***	(0.002)***	(0.005)***
Years Since Last Upgrade				0.164	0.165	0.137
				(0.001)***	(0.001)***	(0.001)***
Years Since Last Upgrade^2				-0.012	-0.012	-0.009
				(0.000)***	(0.000)***	(0.000)***
N	955214	960837	306578	766335	769723	227814
Adjusted R^2	0.078	0.079	0.039	0.388	0.386	0.259
F Statistic	2520.469	2734.166	484.572	11979.469	12074.867	1777.209
Road FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	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 **(1)**	Nat. roads **(2)**	Prov. roads **(3)**	Prov. roads **(4)**	District roads **(5)**	District roads **(6)**
$\log \text{GDP}_{t-2}$	-0.080		-0.584		-0.087	
	(0.185)		(0.506)		(0.118)	
$\log \#\text{Firms}_{t-2}$		-0.080		-0.291		-0.086
		(0.124)		(0.284)		(0.065)
N	241	256	249	265	545	568
Adjusted R^2	0.319	0.310	0.389	0.363	0.091	0.097
Road FE	No	No	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

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 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	-0.421	904	21.272	178.796
	(0.057)***	(0.103)***			
Log Travel t to Prov. Capital	-0.447	-0.652	904	75.217	178.796
	(0.037)***	(0.058)***			
Panel B: Market Potential					
Log Travel t to Nearest City	-0.733	-0.678	1032	21.095	453.576
	(0.137)***	(0.127)***			
Log Travel t to Prov. Capital	-0.969	-0.862	1032	71.353	453.576
	(0.092)***	(0.058)***			

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 (0.020)	0.000 (0.040)	36851	0.701	32
Log Total Hours Worked	-0.012 (0.037)	-0.038 (0.080)	23290	5.150	31.237
Log Total Earnings	0.467 (0.197)**	0.913 (0.399)**	17889	10.711	27.404
Agriculture ... Any Employment (0 1)?	-0.065 (0.018)***	-0.085 (0.043)**	23293	0.418	31.232
... Log Total Hours Worked	-1.398 (1.427)	4.070 (2.868)	23499	13.224	30.918
... Log Earnings	1.182 (0.778)	2.484 (1.473)*	5308	7.824	13.431
Manufacturing ... Any Employment (0 1)?	0.080 (0.023)***	0.100 (0.050)**	23293	0.290	31.232
... Log Total Hours Worked	4.083 (1.134)***	9.817 (2.455)***	23839	12.572	30.933
... Log Earnings	-0.101 (0.206)	0.507 (0.583)	4443	11.198	16.004
Sales and Services ... Any Employment (0 1)?	-0.043 (0.021)**	-0.160 (0.043)***	23293	0.313	31.232
... Log Total Hours Worked	-3.176 (1.374)**	-7.239 (2.458)***	23531	13.628	31.290
... Log Earnings	0.127 (0.251)	0.077 (0.525)	4174	11.047	22.725
Other (Formal) ... Any Employment (0 1)?	0.026 (0.015)*	0.001 (0.029)	23293	0.190	31.232
... Log Total Hours Worked	0.516 (0.753)	-1.113 (1.402)	23293	7.126	31.232
... Log Earnings	-0.928 (0.562)*	-2.407 (1.218)**	3275	4.584	23.136
Other (Informal) ... Any Employment (0 1)?	-0.048 (0.018)***	-0.119 (0.036)***	23293	0.225	31.232
... Log Total Hours Worked	-3.043 (0.924)***	-7.202 (1.739)***	23293	8.052	31.232
... Log Earnings	0.798 (0.618)	1.271 (1.049)	3757	8.643	26.553
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 (0.040)***	0.182 (0.093)*	23129	11.064	39.372
Log of Land Value	0.283 (0.162)*	0.969 (0.322)***	7325	14.806	18.188
Log of Rent Per Room	0.199 (0.063)***	0.726 (0.135)***	19242	8.316	38.708
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)	0.053 (0.051)	0.069 (0.036)*	198	0.137	34.741
Log Share of Recent Migrants	0.609 (0.143)***	1.436 (0.246)***	198	-3.260	21.130
Log Total Recent Migrants	0.434 (0.123)***	1.614 (0.267)***	198	10.014	21.130
Province FE	Yes	Yes			

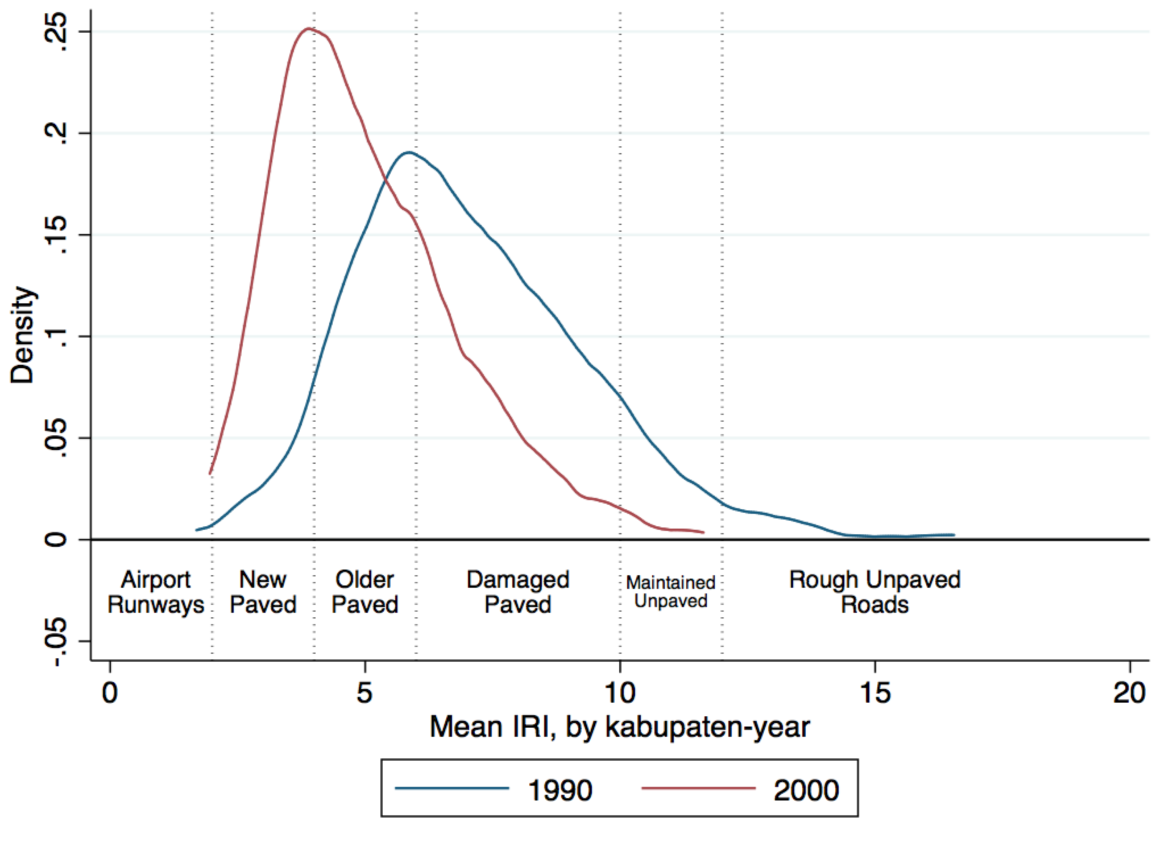
We report the results of cross-sectional regressions of the dependent variable on changes in road roughness. Each cell reports estimates of β from a separate regression, with the dependent variable listed in the row heading. For the migration regressions, controls include logs of 1990 population and 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)***	.	.	.

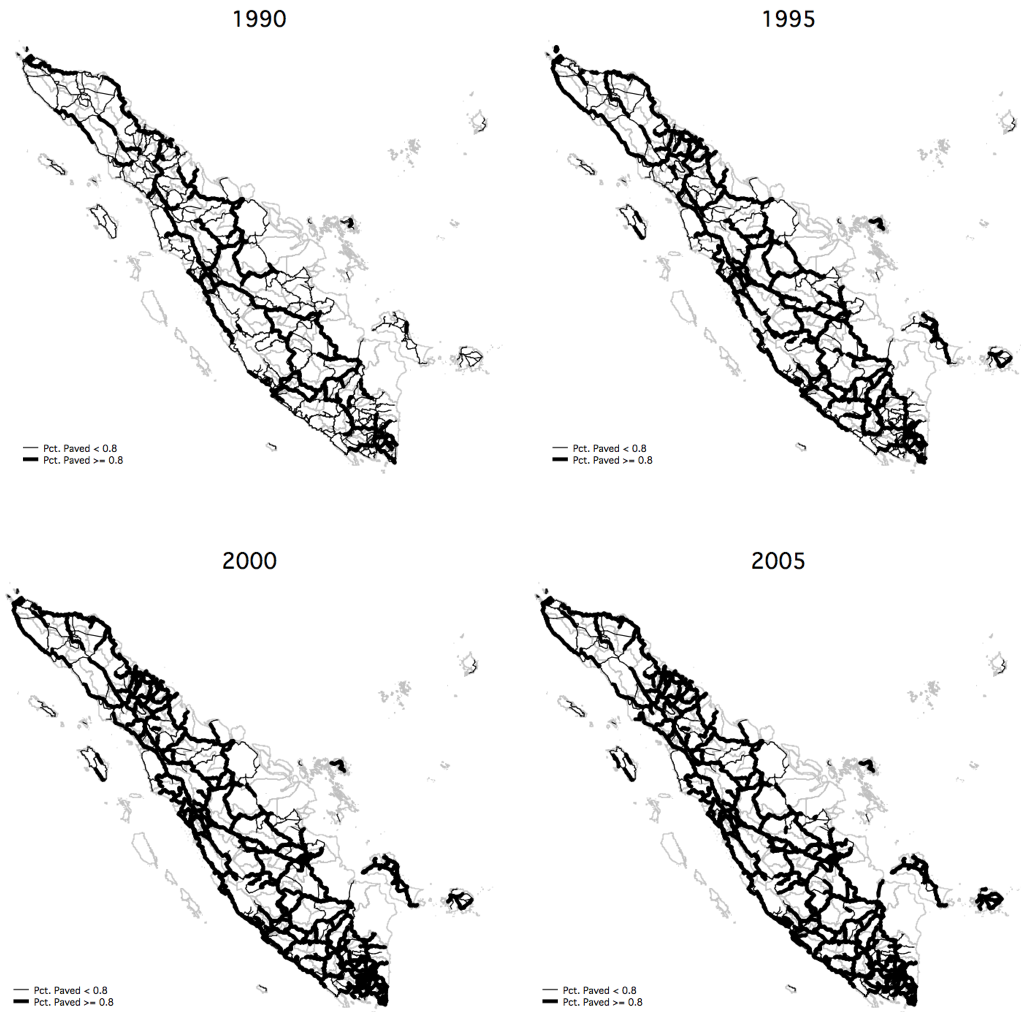
We report the results of community-level panel regressions of the dependent variable on local road quality or market potential (both in logs). Each cell reports β from a separate regression, with the dependent variable listed in the row heading. All regressions include community and year fixed effects, with controls including logs of current population, and non-oil GDRP. Log(Food price) is expressed as deflated Laspeyres index, composed from community level prices of rice, oil, sugar, salt (tradables), beef and fish (perishables) with the corresponding consumption expenditure weights. 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



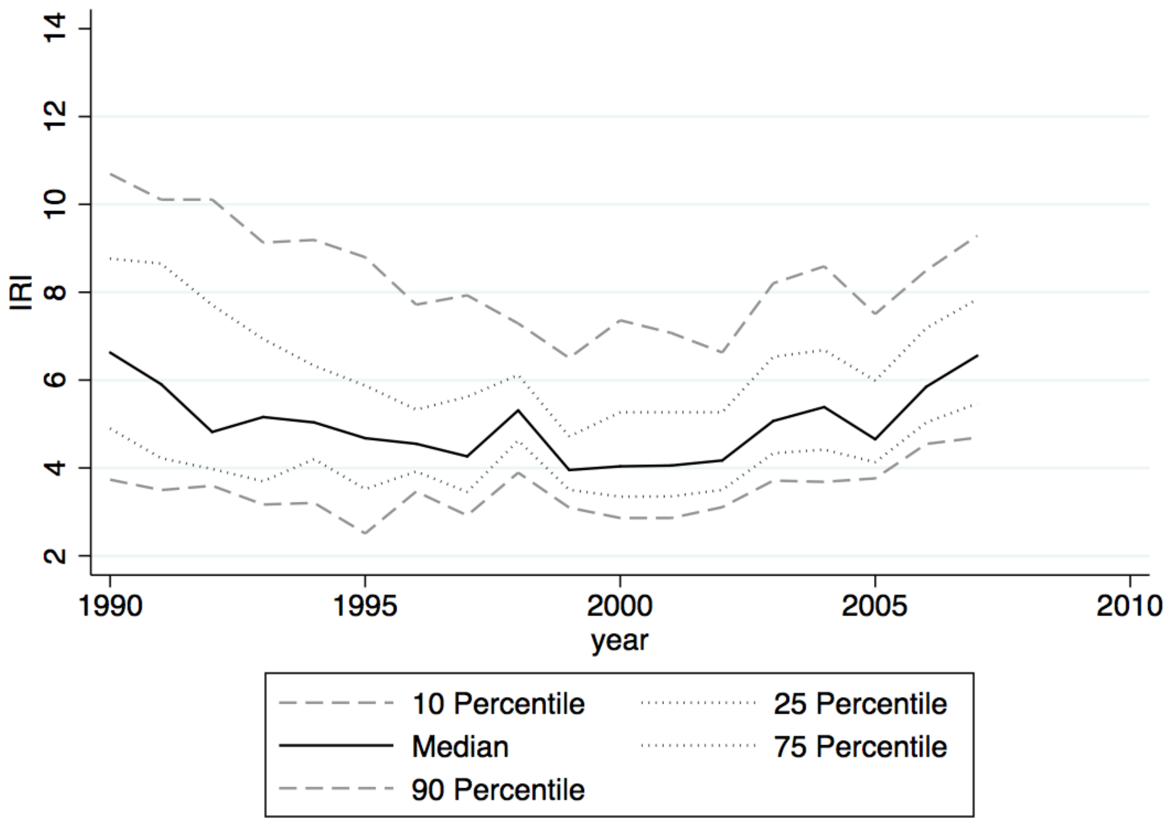
Note: Authors' calculations.

Figure 2: Road Roughness - Sumatra



Note: Authors' calculations.

Figure 3: Changes in Roughness



Note: Authors' calculations.

Figure 4: IFLS Villages

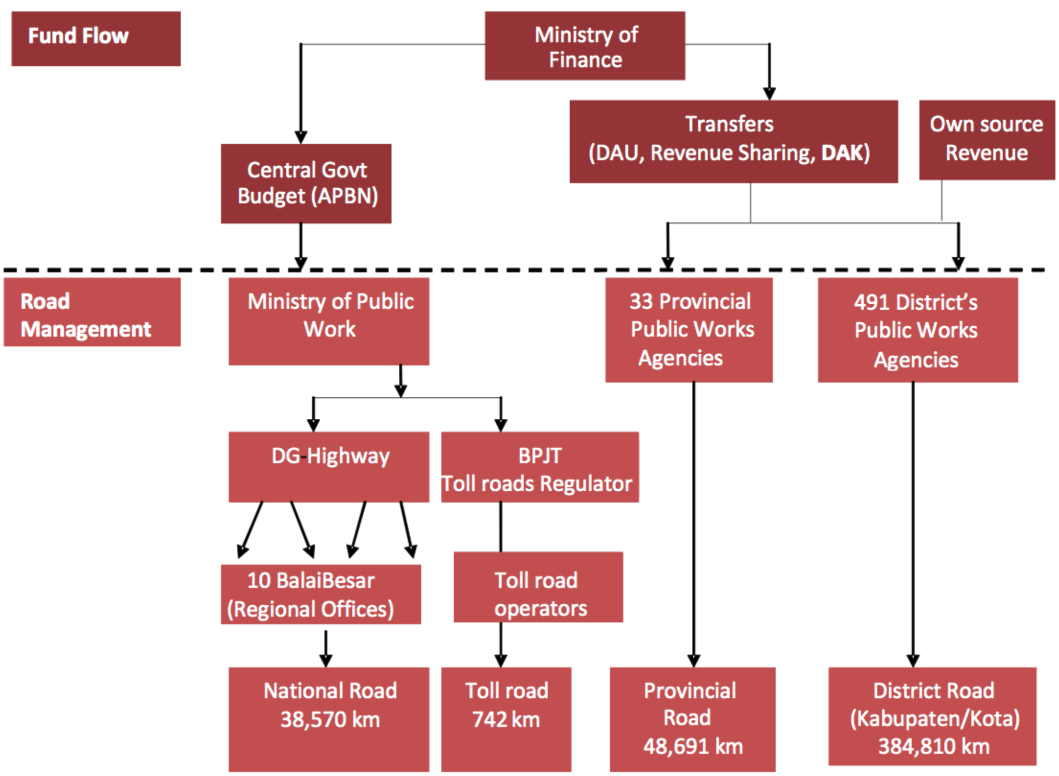
Note: Authors' calculations.

Figure 5: 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 6: Institutional Arrangements for the Road Sector in Indonesia



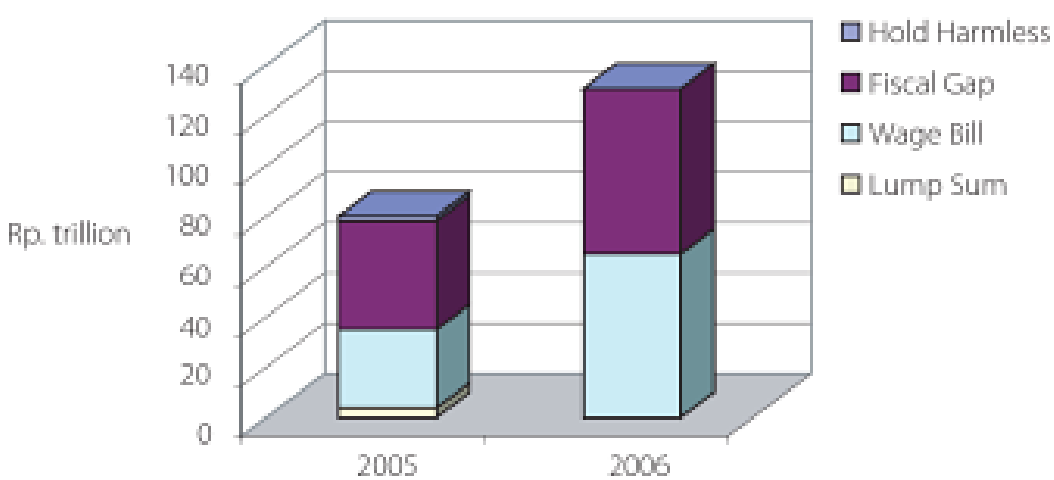
Source: (World Bank, 2012).

Figure 7: 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%

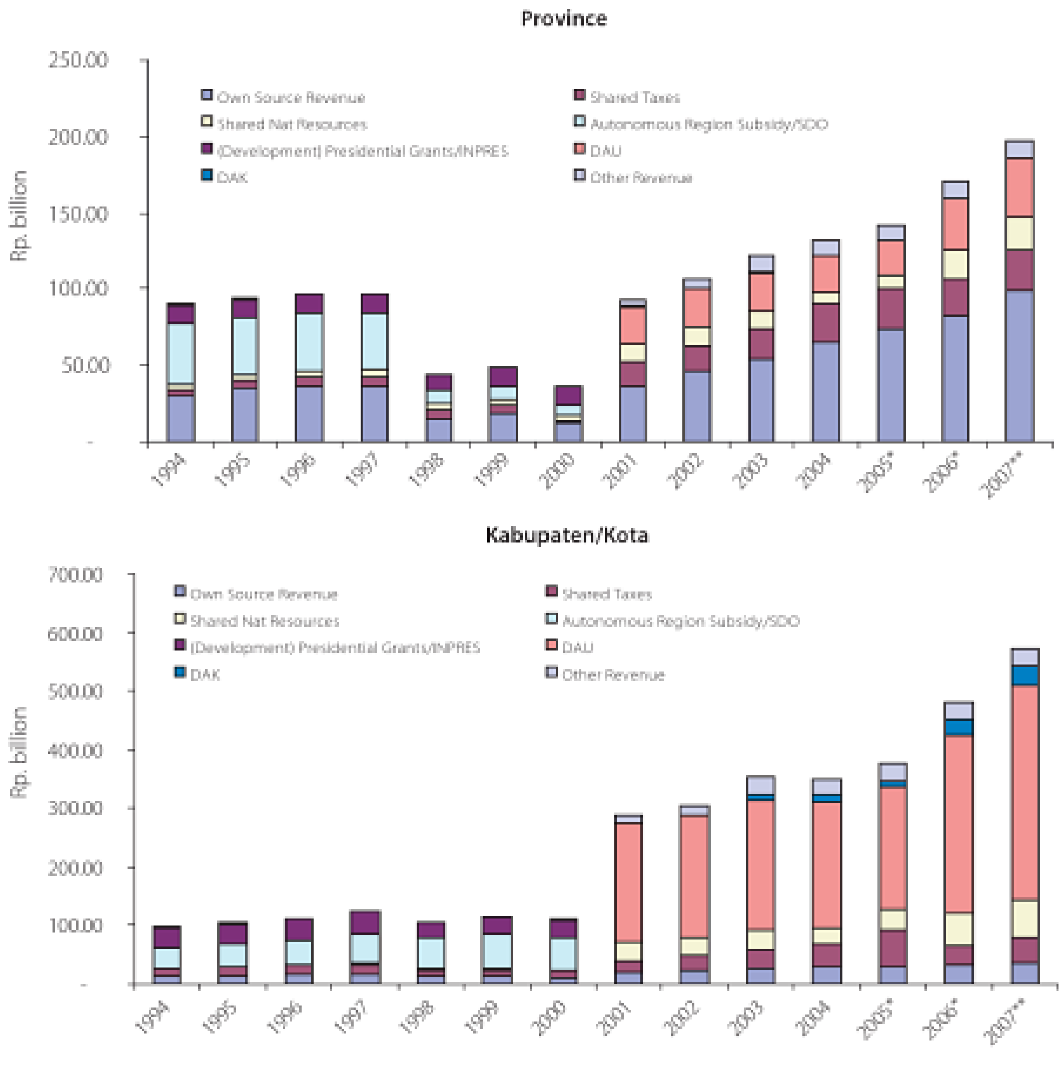
Note: (World Bank, 2012).

Figure 8: Changes in DAU composition over time



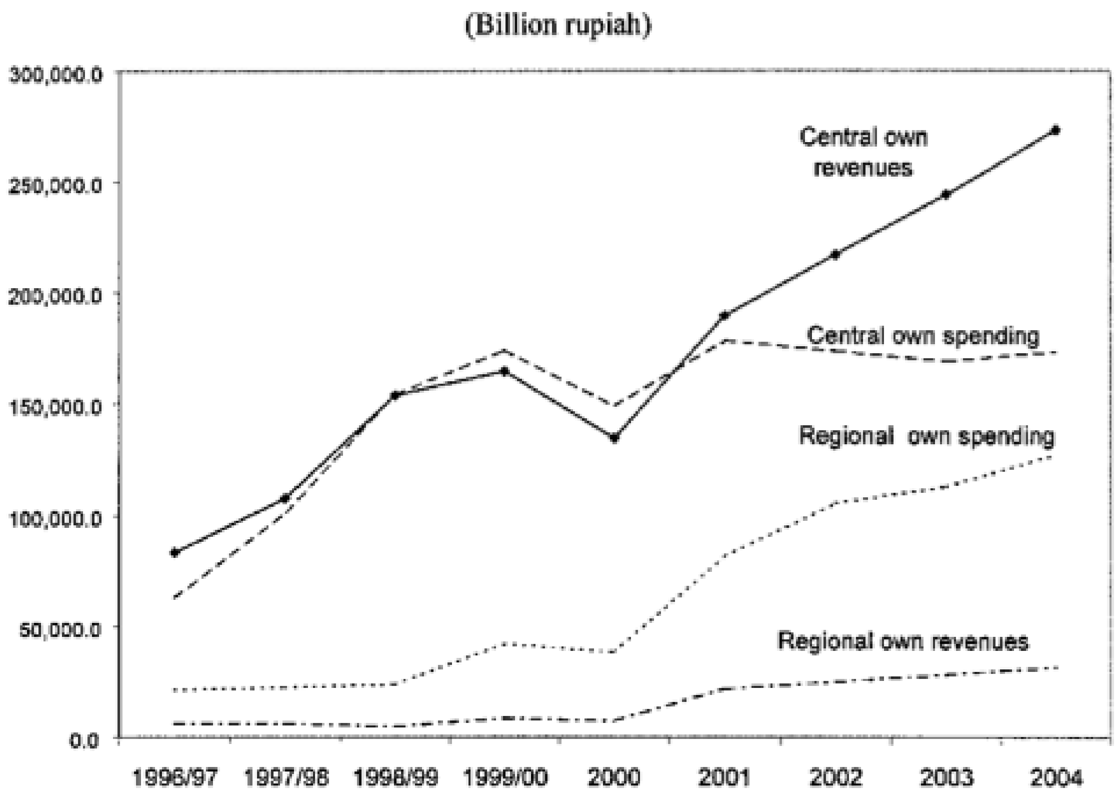
Note: World Bank staff calculation. (World Bank, 2008).

Figure 9: Sub-national revenue over time



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

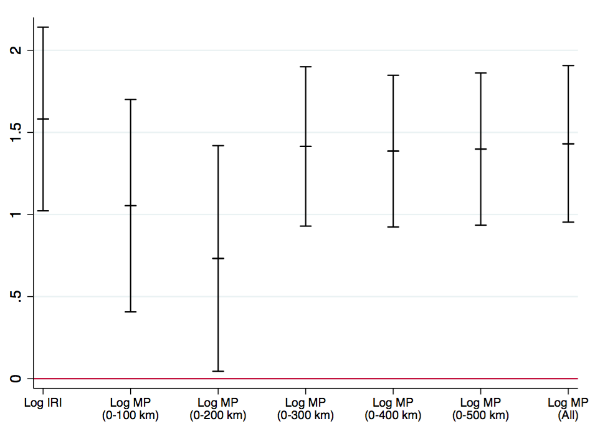
Figure 10: Impact of Decentralization in Indonesia



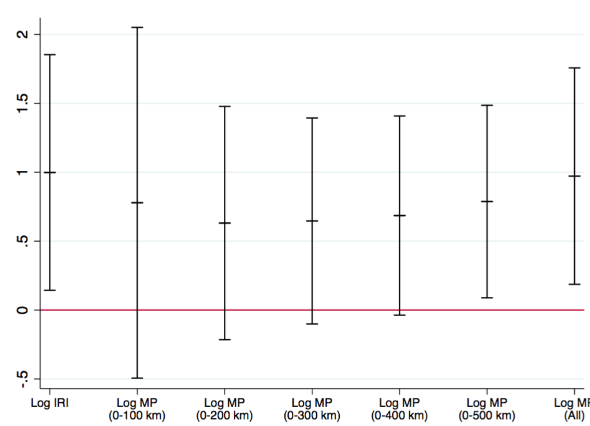
Note: In billion rupiah. (Ahmad and Mansoor, 2002).

Figure 11: Coefficients Plots

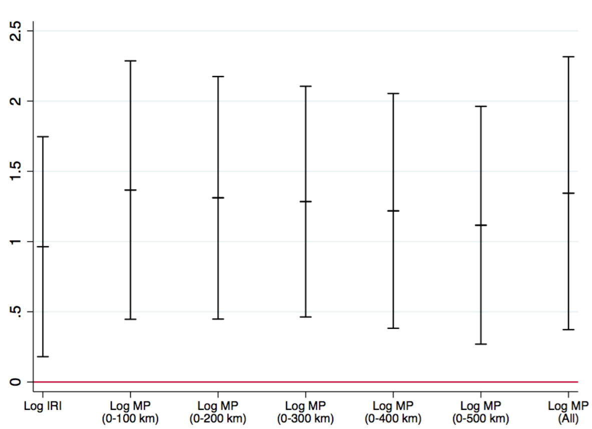
(a) Log # of Opened Firms, District-Year



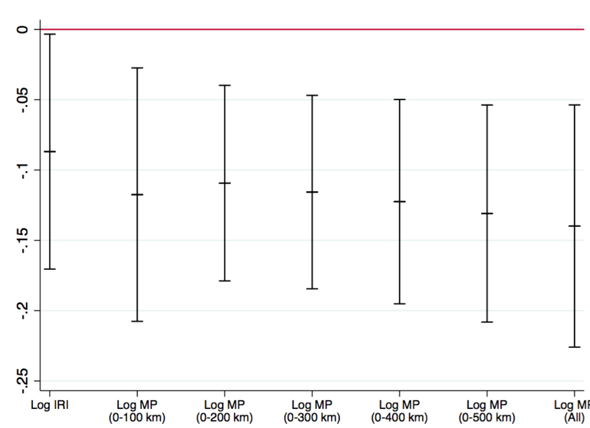
(d) Log # of Workers, District-Year



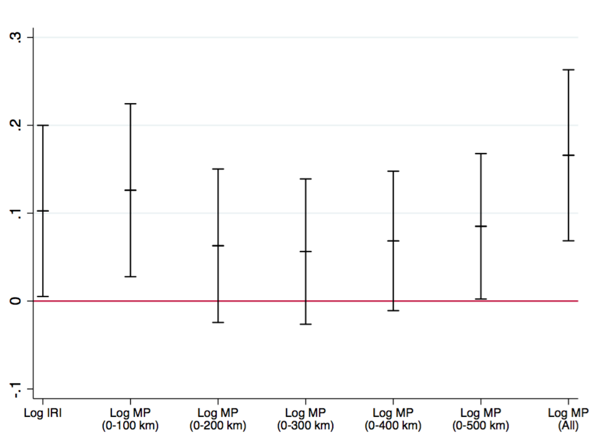
(b) Log Total Earnings, Individual Panel



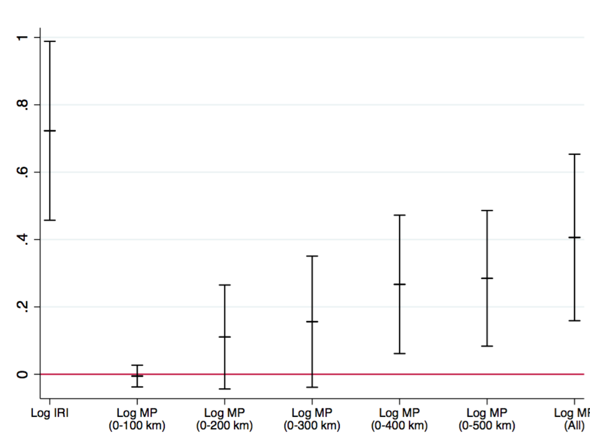
(e) Any Employment in Agriculture? (0 1), Individual Panel



(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.