Spatial networks, incentives, and the dynamics of village economies: evidence from Indonesia

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4

chapter

Economic growth often accompanies spatial inequality. Spatial connection to high-growth centers offers a pathway out of poverty in local economies, by improving economic returns to investment and reducing costs in transportation and the search for both human and physical resources, which alters the allocation of household resources. In general, an improvement in spatial connectivity is expected to increase allocative efficiency in the local economy, because the mobility of resources becomes faster and less costly and price disparity becomes smaller (for example, Minten and Kyle 1999).

However, it is not clear how better spatial connectivity—among neighborhood local areas or between local areas and distant economic centers—changes poverty and income distribution. In other words, it is not clear who gains from better spatial connectivity. Improved spatial connectivity in the local economy may have heterogeneous impacts on households with different endowments. To investigate this issue, we use recently available household panel data from Indonesia.

In rural contexts, once a village is connected by a new road to a nearby town where jobs are available, the household allocation of labor is expected to change so that they gain from earning opportunities in the town's labor market. If entry to the labor market is easier for educated agents, the allocation of labor changes among households with educated members. More educated agents may try to capture better employment or urban market opportunities that are available in larger economic centers farther than the local town (without migrating). In this case, road access to the larger economic center is more important.

Similarly, if the local town has efficient markets for agricultural products, landed farmers will benefit from the new local road, but landless households will not, because farmers have surplus products to sell, whereas landless households do not. Increasing demand for food from larger economic centers may induce some landed farmers to invest in agroprocessing, increasing nonfarm income. In this case, the effects could be heterogeneous across different locations and across households with different endowments.

The recent literature provides some studies suggesting that returns to human and physical capital in rural areas critically depend on spatial connectivity, which affects the allocation of household resources, such as labor (see Fafchamps and Shilpi 2003, 2005; Fafchamps and Wahba 2006). Fafchamps and Shilpi (2003) show that the distance to cities is crucial for determining wage opportunities and employment structure in Nepal, and thus nonfarm employment (either wage or self-employment) is concentrated in and around cities. Since road construction improves the access to (nonagricultural) labor markets or urban consumers, it increases wages and employment choices for rural residents. Cerain types of employment become available with improved spatial linkages. For example, Fujita and Muto (2007) show that the effect of spatial linkages on brand agriculture depends on the differentiation of products.

The connectivity to urban centers can benefit laborer households more than farm (landed) households by improving the access to nonagricultural employment opportunities. Foster and Rosenzweig (2001) present recent evidence from India that the landless prefer public investment in local road construction because it improves their access to labor markets, while the landed prefer investment in irrigation because it augments returns to land.

The improvement in spatial connectivity also has implications for product markets, reducing transportation margins. Minten and Kyle (1999) show that price variations are largely due to transportation costs in the Democratic Republic of Congo. An interesting finding is that traders benefit from bad road conditions, which lower the purchase price of products (thus increasing their profit). Therefore, spatial connectivity can potentially increase farmers' income by reducing traders' profit margin.

Numerous studies have estimated the returns to infrastructure investment such as road construction under various assumptions, mostly at the aggregate level (Binswanger, Khandker, and Rosenzweig 1993; Fan, Zhang, and Zhang 2004). To analyze the dynamic effects of infrastructure investment on income growth at the household level, it is necessary to combine, by household and village locations, both household and spatial panel data over a long span of time with sufficiently large changes in infrastructure.

In this paper, we endeavor to capture the improvement in spatial connectivity by constructing a measure that captures intervillage road quality in a region (from the Indonesian village census). We combine this measure and distance to economic centers: subdistrict, district, and provincial capitals (from the village survey we conducted in 2007). Our main idea is that intervillage road quality determines the means of transportation used in the local economy and therefore the average speed of resource mobility (including human), which affects allocative efficiency in the local economy. Potential gain in allocative efficiency is also affected by the distance to economic centers at different levels, as these economic centers offer different economic opportunities.

Previous studies on the spatial connectivity of rural households were limited in the sense that they perceived connectivity only as access to local towns or as distance from growth centers and were unable to discuss the combination of both. But in actual policy choices, public investment planners face decisions regarding the allocation of resources among trunk roads (which lead to economic centers) and local roads. They also face policy choices regarding the balance between fiscal spending on education and on roads. Therefore, this paper can bridge the gap between academic studies and infrastructure planning.

Empirical results show that improvements in the quality of local roads in the local area (which are positively correlated with speed of transportation) have an impact on income growth and the transition to nonagricultural activities and that the impact depends on the distance to economic centers and household education. Education significantly increases the benefit from an improvement in spatial connectivity, which is augmented by distance from the provincial center. Education and local road quality are complementary, increasing income growth. Therefore, whether the improvement in local connectivity (measured by average road quality) is pro-poor or not depends on village location and the initial household-level endowment of education.

Data

We use data from two sources. First, the main data come from village- and household-level surveys that we conducted in 2007 for 98 villages in seven provinces (Lumpong, Central Java, East Java, West Nusa Tenggara, South Sulawesi, North Sulawesi, and South Kalimantan) under the Japan Bank for International Cooperation (JBIC's) Study of the Effects of Infrastructure on Millennium Development Goals in Indonesia (IMDG). The 2007 village survey captured the physical distance and time to various points of economic activity such as markets, stations, and capital towns. Figure 4.1 shows the location of surveyed villages.

The survey was designed to overlap with villages in the 1994–95 National Farmer's Panel (PATANAS) survey conducted by Indonesian Center for Agriculture Socio-Economics and Policy Studies (ICASEPS) to build household panel data. The 1994–95 PATANAS survey focused on agricultural production activities in 48 villages chosen from different agroclimatic zones in seven provinces. In 2007 we revisited those villages to expand the scope of research through a general household survey conducted under the IMDG survey. In the 2007 round, therefore, we added 51 new villages in the seven provinces.

In the revisited villages, we resampled 20 households per village from the 1994–95 sample and followed the split households. In the new villages, we sampled 24 households from two main hamlets in each village. Because one of the 48 villages in the 1994–95 PATANAS (in West Nusa Tenggara province) was not accessible for safety reasons in 2007, 98 villages were available for various research objectives. In our panel analysis, we constructed household income panel data from 34 villages in six provinces (Lumpong, Central Java, East Java, West Nusa Tenggara, South Sulawesi, and North Sulawesi) using both the 2007 household and 1994–95 PATANAS surveys.[1]

Second, 1996 and 2006 PODES data were used to construct road quality data. PODES is a village census conducted by the Republic of Indonesia's Central Bureau of Statistics.

Descriptive analyses

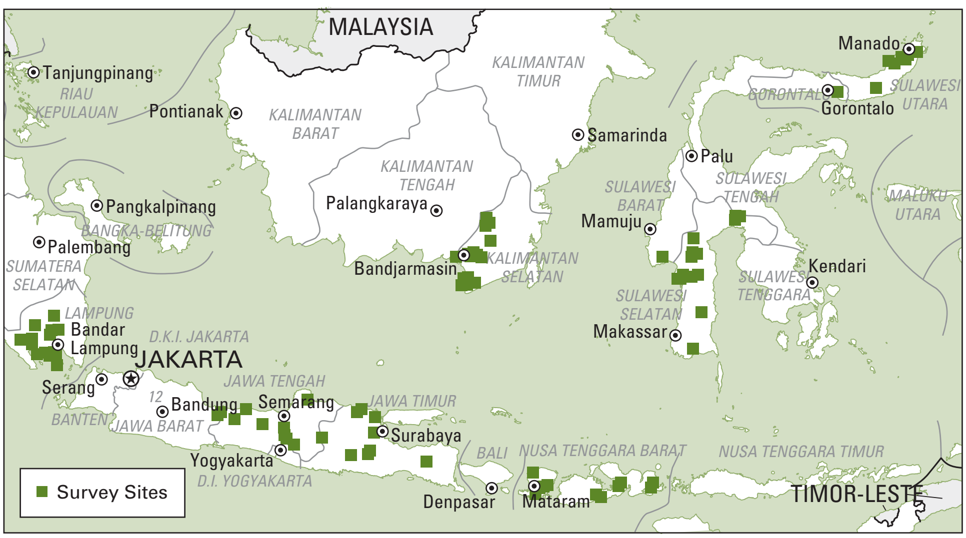
This section describes the data dealing with spatial connectivity (specifically intervillage road improvement and distance to economic centers) and household income (specifically income dynamics and nonfarm self-employment).

Spatial connectivity

In this section we describe village census data (PODES) with a focus on transportation and road quality variables and characterize changes in local road quality in the period of 1996 to 2006. The data cover all villages in the census years. For our research, we use the 1996 and 2006 rounds of PODES, as our household panel data were collected in 1995 and 2007. In the panel analysis, we take the difference between 1996 and 2007 to represent changes in the average quality of roads in local economies.

The PODES data have the information on major intervillage traffic. If the major traffic is on land, the survey asks about the

Figure 4.1 Location of surveyed villages in Indonesia



Source: National Coordinating Agency for Surveys and Mapping for boundaries as of 1990; GPS coordinates collected during IMDG 2007 for the location of surveyed villages.

type of widest road for this purpose: asphalt, concrete, or cone block; hardened; soil; and others. Another question identifies whether four-wheel or larger vehicles are able to use the road all year long. From this information, it is possible to construct indicator variables for (a) major intervillage traffic = land or not, (b) type of widest road = asphalt, concrete, or cone block or not, (c) type of widest road = hardened or not, (d) type of widest road = soil or not, (e) type of widest road = others or not, and (f) four-wheel or larger vehicles can use the road all year long = yes or no.

We use the measure of the type of widest road to capture the speed of transportation in the local economy. The average is taken at the subdistrict, district, and provincial levels in each round.

$$\mathbf{z}_t(j) \equiv \frac{\sum_{m \in N(j)} z_t^m}{\#N(j)}, \tag{4.1}$$

where z_t^m is the indicator variable, which takes the value of 1 if major intervillage traffic is on land and the road is constructed of asphalt, concrete, or cone block (good quality) and 0 otherwise (bad quality), *N(j)* is a set of villages within village *j*'s neighborhood, and *#N(j)* is the number of villages in *N(j)*. Therefore, $\mathbf{z}_t(j)$ is the probability of having good-quality transportation, which is assumed to be positively correlated with the average transportation speed in the local economy.

Table 4.1 shows the provincial averages of asphalt road indicators in 1996 and 2006. To have comparability between the two years, we use 1996 provinces for villages that changed province or district from 1996 to 2006. First, in both years, we observe interprovincial disparities in average road quality. Second, the average proportion of intervillage roads that are made of asphalt has improved in many provinces.

Table 4.2 shows tabulations of villages matched between 1996 and 2007 based on changes in intervillage road quality (asphalt or not). In many provinces, many villages have seen an improvement in intervillage road quality, although a large number of villages have seen no change in quality and a non-negligible number of villages have seen deterioration in quality. The reason for deteriorating road quality is not obvious from the data, but it may be related to inadequate maintenance or the construction of poor-quality new roads.

Table 4.1 Proportion of asphalt roads in intervillage roads in Indonesia, 1996 and 2006 (provincial average)

Province	1996	2006
11	0.45562672	0.39410377
12	0.48859242	0.52783693
13	0.69230769	0.92619926
14	0.39776952	0.48143236
15	0.61111111	0.73608903
16	0.63424867	0.68574200
17	0.74492498	0.72736521
18	0.52244898	0.47041636
31	0.98850575	1.00000000
32	0.68730866	0.65761397
33	0.64077898	0.74067070
34	0.80593607	0.79156909
35	0.55911418	0.67632006
51	0.98452012	0.98798799
52	0.81891026	0.78364566
53	0.44480171	0.40334378
61	0.41470588	0.46736842
62	0.36184211	0.43560606
63	0.63270504	0.66544923
64	0.32412791	0.49311295
71	0.75829726	0.75510204
72	0.57568627	0.63330300
73	0.49590893	0.60324617
74	0.52157830	0.55233853
81	0.56921488	0.64210526
82	0.24639671	0.44170404

Source: Authors' calculations using PODES 1996, 2006.
Note: The unit of observation is the village.

Next, taking the difference between the two rounds, we can see improvement and deterioration in the quality of roads in local economies:

$$\Delta\mathbf{z}(j) = \mathbf{z}_1(j) - \mathbf{z}_0(j). \tag{4.2}$$

In all regions, the changes are symmetrically distributed, with either improvement or deterioration, although the majority shows relatively small changes around 0 (see figure 4.2). At the subdistrict level, improvement and deterioration coexist over the 10 years in Indonesia, which allows us to examine the impact of intervillage changes in road quality on household income dynamics. Comparison of the change in road quality (at the subdistrict level) between Java and non-Java regions shows that areas in Java experienced a faster improvement than areas outside Java.

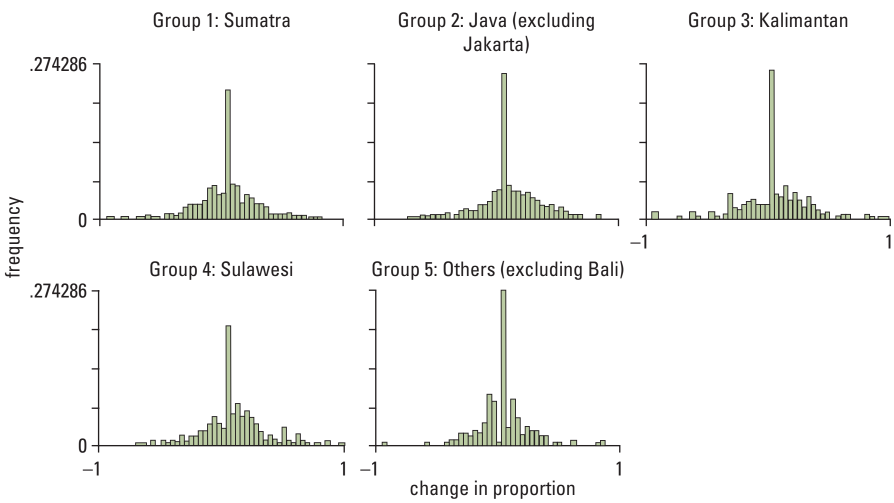
Regarding distance to economic centers, we assume that the physical distance has been constant throughout the period, so it is

Table 4.2 Changes in intervillage road quality (asphalt, concrete, or cone block or not) in Indonesia, by province, 1996–2006

Province	Number of villages: No change: Remain good	Number of villages: No change: Remain bad	Number of villages: Deteriorated	Number of villages: Improved	Number of villages: Total	Percent of villages in each province: No change: Remain good	Percent: No change: Remain bad	Percent: Deteriorated	Percent: Improved	Percent: Difference: improved minus deteriorated
Jawa Barat	516	546	230	128	1,420	36.3	38.5	16.2	9.0	–7.2
Lampung	373	60	53	35	521	71.6	11.5	10.2	6.7	–3.5
Maluku	249	349	91	70	759	32.8	46.0	12.0	9.2	–2.8
Jambi	586	154	101	77	918	63.8	16.8	11.0	8.4	–2.6
South Kalimantan	303	47	42	35	427	71.0	11.0	9.8	8.2	–1.6
East Java	1,067	438	279	250	2,034	52.5	21.5	13.7	12.3	–1.4
Aceh	989	1,907	689	649	4,234	23.4	45.0	16.3	15.3	–0.9
Kalimantan Timur	602	3	8	10	623	96.6	0.5	1.3	1.6	0.3
Bali	1,277	1,277	385	424	3,363	38.0	38.0	11.4	12.6	1.2
Sulawesi Tengah	349	125	71	82	627	55.7	19.9	11.3	13.1	1.8
Central Java	258	0	0	7	265	97.4	0.0	0.0	2.6	2.6
Riau	860	599	139	189	1,787	48.1	33.5	7.8	10.6	2.8
West Nusa Tenggara	188	378	56	78	700	26.9	54.0	8.0	11.1	3.1
Sumatra Barat	261	207	56	78	602	43.4	34.4	9.3	13.0	3.7
Sumatra Selatan	190	357	12	36	595	31.9	60.0	2.0	6.1	4.0
Irian Jaya	1,162	646	157	261	2,226	52.2	29.0	7.1	11.7	4.7
Nusa Tenggara Timur	101	759	25	81	966	10.5	78.6	2.6	8.4	5.8
North Sulawesi	968	695	179	314	2,156	44.9	32.2	8.3	14.6	6.3
Sumatera Utra	152	251	17	49	469	32.4	53.5	3.6	10.4	6.8
Bengkulu	215	37	8	28	288	74.7	12.8	2.8	9.7	6.9
Sulawesi Tenggara	561	423	73	159	1,216	46.1	34.8	6.0	13.1	7.1
South Sulawesi	139	502	18	73	732	19.0	68.6	2.5	10.0	7.5
DKI Jakarta	378	137	64	123	702	53.8	19.5	9.1	17.5	8.4
Kalimantan Barat	4,379	1,361	684	1,441	7,865	55.7	17.3	8.7	18.3	9.6
DI Yogyakarta	268	536	61	171	1,036	25.9	51.7	5.9	16.5	10.6
Kalimantan Tengah	3,653	1,756	807	1,746	7,962	45.9	22.1	10.1	21.9	11.8
Total	**20,044**	**13,550**	**4,305**	**6,594**	**44,493**	**45.0**	**30.5**	**9.7**	**14.8**	**5.1**

Source: Authors' calculations using PODES 1996, 2006.

Figure 4.2 Change in average intervillage road quality (asphalt roads as a proportion of all roads) in select provinces of Indonesia



Source: Authors' calculations using PODES 1996, 2006.

taken as predetermined. This information is important because we hypothesize that the development of spatial connectivity has an uneven impact on village economies, depending on the distance to major points of economic activity. Table 4.3 shows distances to the economic centers in all 98 villages, using data from the 2007 village survey.

Household income

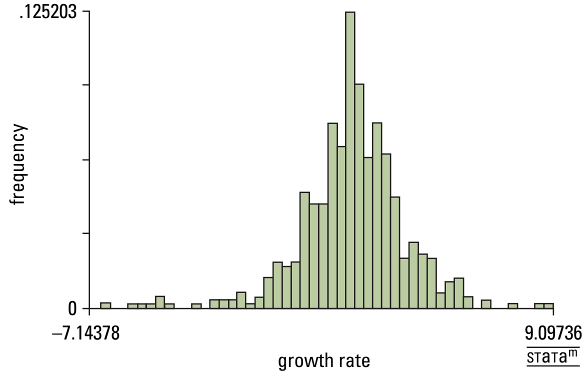
In the analysis of household income dynamics, we use household panel data from two

Table 4.3 Distance to economic centers in select villages of Indonesia
kilometers

Province and village	Subdistrict	District	Province
Lampung			
1	9	37	53
2	13	56	120
3	5	14	75
4	7	7	67
5	3	15	125
6	3.5	42	145
7	12	85	55
8	38	104	12
9	7	85	37
10	37	95	14
11	35	95	14
12	1	10	45
13	5	5	50
14	4	45	82
15	20	80	120
16	15	60	150
Central Java			
1	3	13	110
2	3	15	50
3	3	30	93
4	10	60	120
5	0.05	30	250
6	2	60	225
7	0.1	8	114
8	4	14	90
9	6	5	93
10	6	15	60
11	7	15	270
12	5	8	250
East Java			
1	3	15	190
2	5	20	137
3	5	14	35
4	4	20	38
5	0.7	27	90
6	5	14	115
7	6	20	218
8	4	17	80
9	2	25	93
10	1	8	145
11	2	27	145
West Nusa Tenggara			
1	5	5	50
3	5	25	60
4	0.1	62	300
5	6	25	500
6	2.5	44	640
7	2	19	57
8	5	12	50
9	8	54	250
10	3	4	22
11	0.3	44	45
12	0.1	30	500
13	7	49	650
14	12	13	39
South Kalimantan			
1	0.5	4	102
2	4	12	124
3	3.5	37	40
4	3	10	180
5	0.1	22	170
6	4	22	90
7	18	18	61
8	17	20	67
9	0.1	29	79
10	0.05	17	86
11	15	32	45
12	1.5	16	81
13	3.5	10	93
14	21	45	60
15	50	40	50
16	50	20	50
North Sulawesi			
1	0.3	27	54
2	0.7	18	100
3	1	5	25
4	4	6	27
5	4	40	335
6	6	5	5
7	0.5	18	60
8	6	25	105
9	3.5	16	97
10	1	30	60
11	4	23	59
12	13	20	50
South Sulawesi			
1	3	60	600
2	5	42	279
3	2	7	258
4	3	48	126
5	9	33	352
6	0.5	28	114
7	1	30	140
8	3	17	189
9	3	16	186
10	3.5	13	183
11	8	45	282
12	16	51	280
13	2	16	185
14	1	60	600
15	2	60	530
16	7	70	570
17	7	17	197
18	7	24	250
Mean	6.9	32.7	141.1

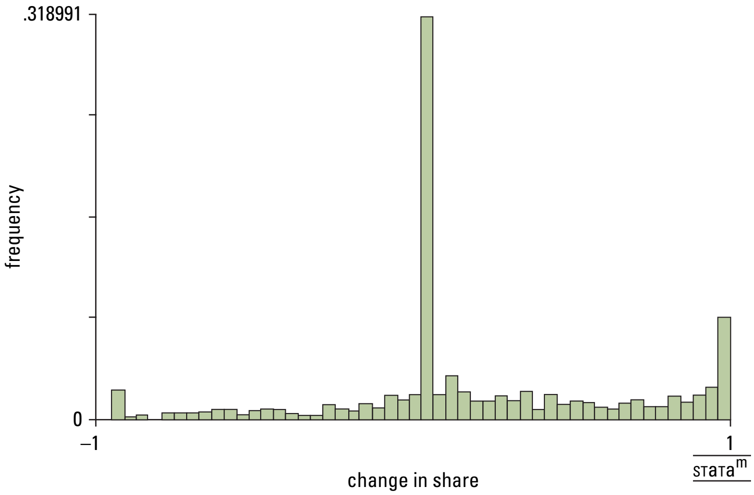
Source: Authors' calculations using IMDG 2007 Version 1.

Figure 4.3 Per capita income growth in select villages of Indonesia



Source: Authors' calculations using PATANAS 1994/95 and IMDG 2007 Version 1.

Figure 4.4 Change in nonagricultural income share in select villages of Indonesia



Source: Authors' calculations using PATANAS 1994/95 and IMDG 2007 Version 1.

rounds conducted in 1995 and 2007 in six provinces, as mentioned. In both surveys, we collected detailed information on income-generating activities. From each activity, we aggregated incomes to construct a household-level income measure.

To merge the income data for 2007 with the data for 1995, we aggregated incomes from original and split households using the 1995 household units. Some households split from the 1995 households (called original households), but it is important to aggregate incomes from both original and split households in 2007 to be comparable with the original households in 1995. The results are quite similar, which implies that attrition (split) bias in our panel analysis is not large (see figures 4.3 and 4.4 on per capita income growth and change in nonagricultural income share).

Table 4.4 shows descriptive statistics of key variables: number of household members ages 15–64, household income, growth of household income, share of nonagricultural income and nonfarm self-employment income in total income, landholding size, and household head's education in 1995. First, the share of both nonagricultural and nonfarm self-employment income increased in the period. Second, about 23.6 percent of the sample households were landless. Third, about 10 percent of the household heads had completed high school or above. Lastly, nominal household income grew about 1.8 percent. However, regression analysis always includes location averages (dummies),

Table 4.4 Descriptive statistics: household income, nonagricultural income share, landholding, and education in select villages of Indonesia

Variable	Number	Mean	Standard deviation	Minimum	Maximum
Number of household members ages 15–64, 1995	673	3.6	1.9	0	11
Number of household members ages 15–64, 2007	673	3.3	1.6	0	11
Household income, 2007 (100,000 rupiah)	674	478	4,330	–3,600	101,000
Household income, 1995 (100,000 rupiah)	674	22.5	39.9	–16.6	712.0
Income growth (percent)	616	1.8	1.9	–6.7	8.6
Nonagricultural income share, 2007 (percent)	674	0.5	0.4	0	1
Nonagricultural income share, 1995 (percent)	674	0.3	0.4	0	1
Nonfarm self-employment income share, 2007 (percent)	674	0.2	0.4	0	1
Nonfarm self-employment income share, 1995 (percent)	674	0.1	0.3	0	1
Landholding size, 1995 (hectares)	674	0.7	1.1	0	10.3
Landless indicator, 1995	674	0.2	0.4	0	1
Head's years of schooling, 1995	658	5.3	3.8	0	17
Head completed at least primary school, 1995 (0 = not completed)	658	0.5	0.5	0	1
Head completed high school or above 1995 (0 = not completed)	658	0.1	0.3	0	1

Source: Authors' calculations using PATANAS 1994/95 and IMDG 2007 Version 1.

which control price changes specific to each location (village).

Provincial averages are compared in table 4.5. First, the shares of nonagricultural income in 2007 are higher in Java provinces than outside Java. Second, this does not necessarily imply higher income (or growth) in Java provinces. Third, landholding size is smaller in Java provinces than outside Java. It is easy to link the diminishing role of land with the increase in nonagricultural activities in rural areas, but this does not mean higher income or higher income growth in our sample.

To merge the household panel data with spatial data on road quality constructed from PODES (1996–2006), we use the information on subdistrict, district, and provincial identification. In the analysis, we interact subdistrict- and district-level road quality variables with household and village-level variables such as education and distance to the district center.

Figure 4.5 (panel A) shows the relationship between a change in the proportion of asphalt roads (at the subdistrict level) and *per capita* income growth in our sample. Since price change and province-level aggregate factors affect income growth (as well as the change in road quality), we control province effects to obtain the residuals. Therefore, the figure shows the effect of a change in local road quality on the residuals. Changes in local road quality and income growth are positively related, which supports our hypothesis.

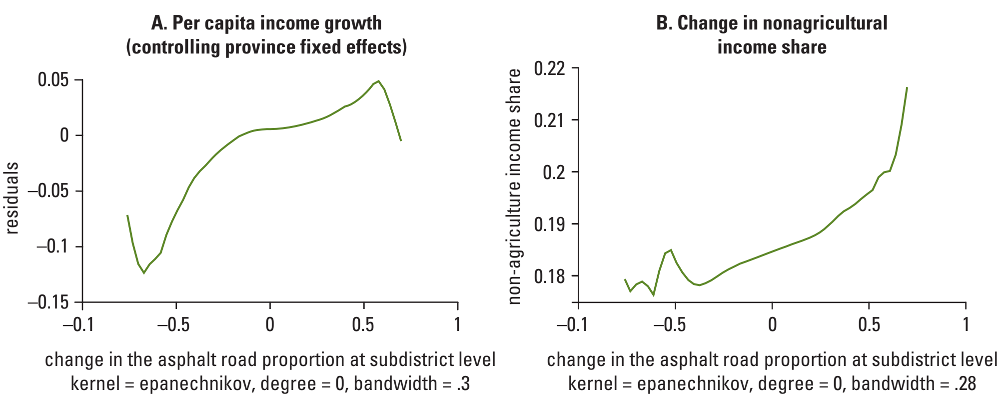
Second, figure 4.5 (panel B) depicts the relationship between changes in the proportion of asphalt roads and the share of nonagricultural income. It clearly shows a

Table 4.5 Provincial averages: household income, nonagricultural income share, landholding, and education in Indonesia

Variable	Lampong	Central Java	East Java	West Nusa Tenggara	North Sulawesi	South Sulawesi
Number of household members ages 15–64, 1995	3.7	3.4	3.5	3.3	2.9	4.2
Number of household members ages 15–64, 2007	3.2	3.2	3.3	3.6	3.1	3.7
Household income, 2007 (100,000 rupiah)	223.0	593.0	208.0	527.0	414.0	977.0
Household income, 1995 (100,000 rupiah)	17.3	21.2	34.4	10.3	25.3	21.0
Income growth (percent)	2.2	1.9	1.6	1.9	2.1	1.3
Nonagricultural income share, 2007 (percent)	0.2	0.7	0.6	0.4	0.7	0.4
Nonagricultural income share, 1995 (percent)	0.1	0.5	0.3	0.4	0.5	0.2
Nonfarm self-employment income share, 2007 (percent)	0.1	0.3	0.3	0.2	0.3	0.3
Nonfarm self-employment income share, 1995 (percent)	0.0	0.2	0.1	0.2	0.2	0.1
Landholding size, 1995 (hectares)	1.2	0.2	0.3	1.0	1.0	1.0
Landless indicator, 1995	0.1	0.5	0.4	0.2	0.1	0.0
Head's years of schooling, 1995	5.0	5.2	4.1	4.6	7.0	6.3
Head completed at least primary school, 1995 (0 = not completed)	0.5	0.4	0.5	0.5	0.6	0.6
Head completed high school or above, 1995 (0 = not completed)	0.1	0.1	0.0	0.1	0.2	0.2

Source: Authors' calculations using PATANAS 1994/95 and IMDG 2007 Version 1.

Figure 4.5 Impact of change in the proportion of asphalt roads at the subdistrict level on per capita income growth and change in nonagricultural income in select villages of Indonesia



Source: Authors' calculations using PODES 1996, 2006; PATANAS 1994/95; and IMDG 2007 Version 1.

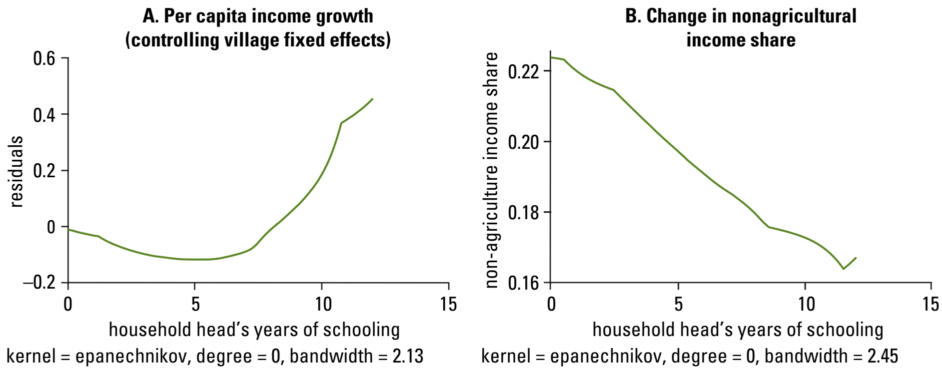
positive association between the two changes. Although we face some identification issues in the estimation we conduct below, these relationships back up our hypothesis.

Next we investigate the relationship between the household head's years of schooling and income growth or change in nonagricultural income share. In this exercise, we use observations (villages) that experienced a positive change in road quality in their subdistrict. Figure 4.6 (panels A and B) shows per capita income growth and nonagricultural income share, respectively. By controlling village effects we get the residuals to, observe intravillage variations. An interesting finding is that, as the household head's years of schooling increase, income growth stays intact up to around completion of junior high school, but it increases substantially from completion of senior high school or higher. There seems to be a threshold in level of schooling beyond which a change in local road quality and education jointly increase the impact on income growth.

In contrast, figure 4.6 (panel B) shows a clear negative (monotonic) effect on change in nonagricultural income share. Less-educated households (measured by the household head's schooling) are likely to have a higher share of nonagricultural income (activity) when road quality improves in their neighborhood.

We describe nonagricultural income opportunities in rural Indonesia, using the 2007 household survey data for 98 villages, with the focus on nonfarm self-employment and its linkage to the spatial connectivity of villages to economic centers. As shown in table 4.6, the mean share of nonagricultural income in total household income is about 44 percent, and the

Figure 4.6 Impact of years of schooling of household head on per capita income growth and change in nonagricultural income in select villages of Indonesia



Source: Authors' calculations using PATANAS 1994/95 and IMDG 2007 Version 1.
Note: Both figures use observations with change in the subdistrict-level intervillage proportion of asphalt roads greater than zero.

Table 4.6 Nonagricultural income share and share of households with self-employment activity in select villages of Indonesia, by distance from economic centers
share in percentages; distance in kilometers

		Distance to district center			Distance to provincial center			
Indicator	**Total**	**0–15**	**16–30**	**30 or more**	**0–60**	**61–120**	**121–400**	**400 or more**
Mean share in household income by								
Nonagricultural sector								
Self-employment (nonfarm)	22	21	24	21	26	22	20	19
Nonagriculture employment	22	30	21	17	27	22	19	16
Agricultural sector								
Farm activities	36	32	38	39	28	38	43	42
Agriculture employment	19	18	17	23	20	19	18	23
Share of households with								
At least one self-employment activity	37	32	40	37	41	37	33	33
At least one manufacturing activity	13	11	12	16	15	10	12	18
Distribution of all households by distance	100	30	37	33	33	28	31	9

Source: Authors' calculations using IMDG 2007 Version 1.

share of nonagricultural income declines as the distance from either the district or provincial center increases. Within nonagricultural income, which is composed of nonagricultural labor income and nonfarm self-employment income in this analysis, the share of nonagricultural labor income declines with distance from economic centers. However, the mean share of nonfarm self-employment income in household income does not necessarily decline.

In fact, the distance from the district center does not necessarily reduce the share of households that engage in nonfarm self-employment activity. In particular, this is the case for self-employment activities that involve manufacturing or processing activities. For example, the share of households with at least one nonfarm self-employment manufacturing activity is 11 percent among households living within 15 kilometers of the district center, while the share is 16 percent among those farther than 30 kilometers. Manufacturing activities account for nearly half of self-employment activities in the survey. The main products include processed food, such as dried fish and crackers, wood (or bamboo) products, and garments (see table 4.7).

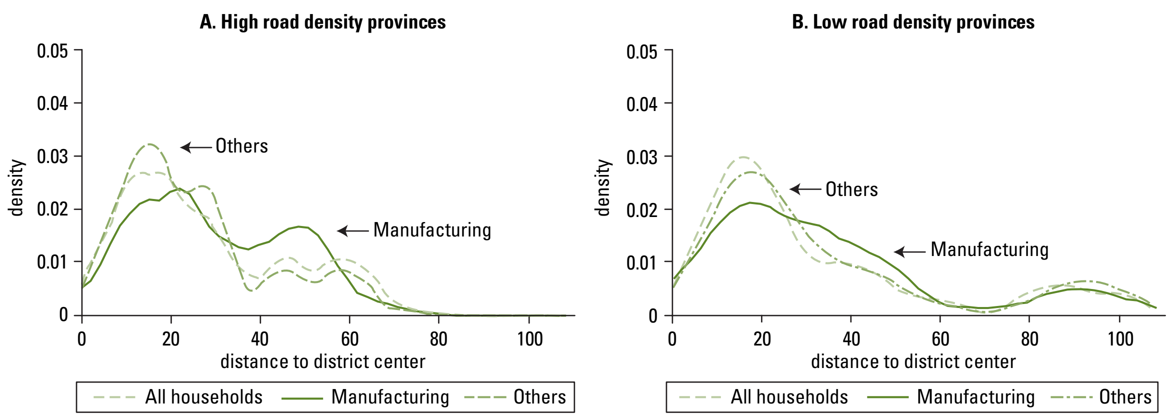
Next, we illustrate the density (frequency) of households with self-employment activities by distance from district centers, using figures based on kernel density estimates.[2] Our goal is to understand how nonfarm self-employment activities are linked with spatial connectivity of villages to economic centers and what type of self-employment activities are made possible by spatial linkages. In figures 4.7 and 4.8, we compare the density pattern of households having at least one self-employment manufacturing activity with the density pattern of households having other self-employment activities. The density pattern of all households (either with or without self-employment) is also presented as a reference (dotted lines). We

Table 4.7 Type of self-employment activities in select villages of Indonesia, by distance to economic centers
share in percentages; distance in kilometers

		Distance to district center			Distance to provincial center			
Activity	**Total**	**0–15**	**16–30**	**30 or more**	**0–60**	**61–120**	**121–400**	**400 or more**
Manufacturing								
Processed food	26.9	25.1	26.3	29.1	26.3	25.9	28.8	26.3
Wood, bamboo products	8.2	4.2	3.8	16.7	10.5	5.5	3.4	25.0
Cloth, textiles	6.3	8.7	6.9	3.5	5.9	4.8	8.5	5.3
Building materials	0.5	0.7	0.5	0.3	0.3	0.7	0.3	1.3
Others	6.6	7.7	5.7	6.6	6.7	10.0	3.4	5.3
Nonmanufacturing	51.6	53.7	56.7	43.8	50.4	53.1	55.6	36.9
Total	100	100	100	100	100	100	100	100

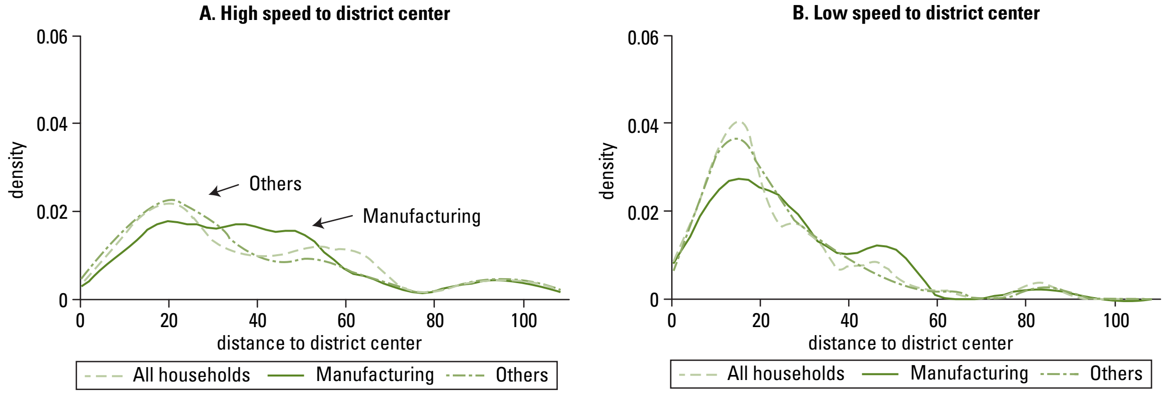
Source: Authors' calculations using IMDG 2007 Version 1.

Figure 4.7 Self-employment activities, by province-level road density in select villages of Indonesia



Source: Authors' calculations using IMDG 2007 Version 1.

Figure 4.8 Self-employment activities, by speed to district center in select villages of Indonesia



Source: Authors' calculations using IMDG 2007 Version 1.

also separate households into two groups—one with better spatial connectivity to the economic centers and one without—and compare the results.[3]

Figure 4.7 (panels A and B) shows that self-employment manufacturing activities exist more at distant (but not very distant) places from district centers. This relationship is particularly evident among households in provinces where the density of national and provincial roads is relatively high than among those where it is relatively low. This implies that improving road networks beyond the district level may enable manufacturing self-employment activities to emerge at distant places from district centers (but not very distant places). Although we need further investigation about why manufacturing activities are generally high in villages located between 40 and 55 kilometers from the district center, this may be related to better access to local resources (for example, woods)[4] and the reasonable range of transportation time or cost (for example, within two hours) needed to reach more consumers, including those in urban provincial centers.

Figure 4.8 (panels A and B) shows similar density patterns to the previous ones. That is, self-employment manufacturing activities exist at distant (but not very distant) places from the district center. However, there is no clear difference in this pattern between households in villages where speed of access to the nearest district center is relatively high or where speed is relatively low.[5] This implies that the possibility for distant households to engage in nonfarm self-employment activities may not be changed by an improvement in district-level roads via faster speed (reduced time) of transportation.

Empirical framework

In the analysis we estimate the following equations on income growth and change in nonagricultural income share, both first differenced between 1995 and 2007 to eliminate fixed effects. The equations for both income growth and nonagricultural income share are written as:

$$\Delta y_{ij} = \alpha + \gamma_{11}\Delta z(j) + \gamma_{12}x_{ij}^{0}\Delta z(j) + \gamma_{21}d_j\Delta z(j) + \gamma_{22}x_{ij}^{0}d_j\Delta z(j) + \Delta\varepsilon_{ij}, \qquad (4.3)$$

where Δy_{ji} is income growth (or change in nonagricultural income share) for household i in village j, $\Delta \mathbf{z}(j)$ is change in the average road quality in the neighborhood of village j, d_j is the distance to a center (discussed below), x_{ij}^{0} is household i's landholdings and level of education in the initial period, and ε_{i_j} is an error term. As mentioned, fixed effects are differenced out.

We assume that distance to the economic activity center is predetermined and so is taken as exogenous. The economic activity point can be the subdistrict, district, or provincial center. The interaction of $\Delta \mathbf{z}(j)$and d_j captures how the benefit from an improvement in spatial connectivity varies with village location and distance from economic activity points.

In the above specification, we also attempt to capture heterogeneous effects of the spatial development by the initial-stage holding of assets and endowment of education at the household level. We use the information on landholding size and household head's education in 1995.

The error term potentially consists of aggregate and household-specific shocks: $\varepsilon_{ij} = \nu_j + \xi_i$. To control province-specific shocks, we could include province dummies. However, village-specific shocks are correlated with local economic development, which is again correlated with dynamic change in average road quality. Thus $E\left[\Delta\nu_j \Delta \mathbf{z}(j)\right] \neq 0$. In the estimation below, therefore, we control village-level dynamic shocks in the first-differenced specification.

$$\Delta y_{ij} = \alpha + \gamma_{12} x_{ij}^{0} \Delta z(j) + \gamma_{22} x_{ij}^{0} d_j \Delta z(j) + villagedummies + \Delta\zeta_{ij}. \quad (4.4)$$

This specification enables us to see intra-village variations in the response to the development of spatial connectivity (as the village average is controlled). Village-specific income shocks (affecting growth) are controlled by village dummies. We assume that the correlation between household-specific shocks and area-wide spatial development is not important.

We use income aggregated from both original and split households in 2007. Therefore, our results are robust to attrition bias potentially arising from endogenous household split dynamics. In the analysis, however, the migration process of individuals is taken as exogenous, which may bias our estimates given that the migration process defines the denominator used to calculate per capita income.

Empirical results

In this section we summarize our main results from the household analysis. Specifically, we examine household income growth, changes in the share of nonagricultural income, and changes in the share of nonfarm self-employment income. In preliminary analyses, we found that the subdistrict-level measure of road quality explains these changes better than district-level and province-level measures of road quality, probably because it has enough variations in the sample and because the development of localized spatial connectivity is important to opening access to wider economic activities (such as are available at district and provincial centers).

To capture potential heterogeneous effects of improvement in the subdistrict average road quality on income growth, we introduce some heterogeneity in the analysis: household head's education level and landownership in 1995 at the household level and distance to subdistrict, district, and provincial centers at the village level.[6]

The main analytical point is to investigate the role of postprimary education and initial landholding in income growth when spatial connectivity is improving in the local neighborhood and then to investigate the relationship between this and the connectivity with more distant economic centers. We include village dummies to control village-specific shocks containing price changes specific to the village economy.

In table 4.8, columns 1 and 2 use years of schooling completed, interacted with the distance to subdistrict, district, and provincial centers. The results confirm that the schooling effect is significantly positive (in the specification with the squared term). Interactions with distances are not significant. Column 3 uses the indicator that takes the value of 1 if the household head has completed high school or higher and 0 otherwise. Consistent with figure 6 (panel A), the effect is significantly positive.

The effect increases as the distance from the provincial center increases, and it decreases as the distance from the district center increases. Returns to schooling decrease if the village is far from the district center, but distance from the provincial center significantly augments the returns. Thus if the village is near the local center (district center) but the local economy is located far from the provincial center, the benefit from the improvement in spatial connectivity is larger among relatively educated villagers.

These results suggest that being a local center in a remote area is key. The marginal benefit from an improvement in local road quality is large in remote areas, probably because capital accumulation is at a low level. However, our results show that the district center is always important in the

Table 4.8 Change in average road quality and per capita income growth in select villages of Indonesia

Independent variable	(1)	(2)	(3)	(4)	(5)
Educ	0.0903	0.2191	1.7370	0.2184	1.7614
	(1.16)	(1.86)	(1.80)	(1.79)	(1.93)
Educ squared		–0.0121		–0.0112	
		(1.08)		(1.00)	
Educ_Distance subdistrict	–0.0027	–0.0030	–0.0154	–0.0021	–0.0083
	(1.56)	(1.62)	(0.49)	(1.00)	(0.28)
Educ_Distance district	–0.0044	–0.0033	–0.1312	–0.0044	–0.1356
	(1.03)	(0.66)	(2.25)	(0.84)	(2.43)
Educ_Distance province	0.0004	0.0003	0.0129	0.0004	0.0132
	(1.17)	(0.93)	(2.70)	(1.04)	(2.89)
Land size				0.0122	–0.0143
				(0.03)	(0.04)
Land_Distance subdistrict				–0.0125	–0.0099
				(1.13)	(0.97)
Land_Distance district				0.0230	0.0232
				(1.42)	(1.57)
Land_Distance province				–0.0026	–0.0027
				(1.86)	(2.07)
Village dummies	Yes	Yes	Yes	Yes	Yes
R^2	0.1069	0.1080	0.1093	0.1105	0.1119
Number of observations	589	589	589	589	589

Source: Authors' calculations using PATANAS 1994/95, PODES 1996, 2006, and IMDG 2007 Version 1.
Note: Numbers in parentheses are absolute *t*-values, using robust standard errors with village-level clusters. Education variable for columns 1, 2, and 4: years of household head's schooling completed. Education variable for columns 3 and 5: 1 = household head completed high school or higher; 0 = otherwise. The dependent variable is per capita income growth; the independent variables are interacted with change in average road quality.

local economy, given localized economic interactions at the district level. There seem to be two important dimensions in economic connectivity: links to the local economy (district capital) and a larger economic demand center (provincial capital). In the former, proximity to the center is always beneficial for the educated, but areas far from the center (that is, districts far from the provincial capital) are more likely to benefit from an improvement in local road quality. Regardless of the interaction with distance, education always increases the marginal benefits from an improvement in local road quality.

Columns 4 and 5 include the effects of landholding size. Although landholding does not show significant effects on income growth, the exercise proves the robustness of our previous findings on schooling.

Land is an important conventional input in agricultural production. But because the land is already in use in 1995, its conversion to nonagricultural or financial resources always incurs opportunity costs. In our findings on income dynamics, land does not matter in income growth or in nonagricultural transition, which does not exclude its static contribution to agricultural production.

Next we examine a change in the share of nonagricultural income (see table 4.9). Columns 1 and 2 examine the effects of schooling on the share of nonagricultural income. Consistent with figure 4.6 (panel B), we find that schooling decreases the change in nonagricultural income share. That is, the (positive) effect of road quality is larger among uneducated households. Distance from the subdistrict center diminishes this effect.

Columns 3 and 4 include the size of landholding interacted with the distance to economic centers. Landholding does not matter in the transition to nonagricultural activities. Education effects remain robust with landholding size.

There are three possible reasons for the negative effect of schooling on the change in share of nonagricultural income. First, the educated are more likely to have nonagricultural income opportunities than the less educated at the initial stage, and therefore the improvement in local road quality has a smaller marginal effect on the transition to

Table 4.9 Change in average road quality and nonagricultural income share in select villages of Indonesia

Independent variable	(1)	(2)	(3)	(4)
Educ	–0.0652	–0.5900	–0.0692	–0.6453
	(2.33)	(2.2)	(2.44)	(2.27)
Educ_Distance subdistrict	0.0013	0.0549	0.0009	0.0612
	(0.78)	(5.45)	(0.59)	(5.66)
Educ_Distance district	0.0019	0.0045	0.0022	0.0061
	(0.77)	(0.20)	(0.90)	(0.26)
Educ_Distance province	–0.0001	–0.0001	–0.0001	–0.0002
	(0.47)	(0.03)	(0.65)	(0.10)
Land size			0.2200	0.2060
			(1.25)	(1.16)
Land_Distance subdistrict			0.0052	–0.0036
			(1.22)	(0.67)
Land_Distance district			–0.0061	–0.0044
			(1.22)	(0.93)
Land_Distance province			–0.0001	–0.0001
			(0.05)	(0.30)
Village dummies	Yes	Yes	Yes	Yes
R^2	0.1049	0.1004	0.1049	0.1073
Number of observations	644	644	644	644

Source: Authors' calculations using PATANAS 1994/95, PODES 1996, 2006, and IMDG 2007 Version 1.
Note: Numbers in parentheses are absolute *t*-values, using robust standard errors with village-level clusters. Education variable for columns 1 and 3: years of household head's schooling completed. Education variable for columns 2 and 4: 1 = household head completed high school or higher; 0 = otherwise. The dependent variable is the change in nonagricultural income share; the independent variables are interacted with change in average road quality.

the nonagricultural sector among the educated. Second, the more educated households also have more assets for agricultural production, and thus the improvement in road quality increases the productivity of their farm activities.

Third, individual-level selectivity may cause this result. At the individual level, the educated are more likely to move out of the household over time to pursue higher-income opportunities in nonagricultural sectors. The comparison of completed schooling between current members and nonmembers shows higher average schooling among nonmembers. In the household with an educated head, other members are also likely to be educated. Therefore, if the migration selection is important in the period of 1995–2007, an inverse correlation between schooling (at the household level) and the transition to nonagricultural work is feasible. This is because educated agents migrate, and relatively less educated agents stay.

Yamauchi et al. (2008) and Dewina and Yamauchi (2008) recently showed evidence supporting the above third possibility. The young and educated, relative to the household head, tend to move out of their households (Dewina and Yamauchi 2008). If out-migrants work in nonagricultural sectors, the share of labor supplied in non-agricultural sectors in the extended family (including out-migrants) increases as the local spatial connectivity improves and the household head's education is greater, and the distance from provincial capital augments the positive complementary effect (Yamauchi and others 2008).

Table 4.10 shows results for a change in nonfarm self-employment as a share of income. We use the same specifications adopted in the previous analyses. In column 1, we find that the schooling effect critically depends on village location. Distance from the provincial center reduces the schooling effect, while distance from the subdistrict center increases the effect. This probably means that nonfarm business activities tend to pay off in areas close to economic centers with large (heterogeneous) demand such as the provincial center. Large demand enables households to cover a relatively large setup cost. The distance effects are all negative in the landholding effect, which is also consistent with our finding.

Table 4.10 Change in average road quality and nonfarm self-employment income share in select villages of Indonesia

Independent variable	(1)	(2)
Educ	0.0676	–0.0016
	(0.33)	(0.01)
Educ_Distance subdistrict	0.0077	0.0183
	(1.95)	(3.26)
Educ_Distance district	0.0081	0.0099
	(1.13)	(1.20)
Educ_Distance province	–0.0021	–0.0022
	(4.61)	(4.24)
Land size		0.1860
		(1.48)
Land_Distance subdistrict		–0.0065
		(2.01)
Land_Distance district		–0.0017
		(0.52)
Land_Distance province		–0.0004
		(1.63)
Village dummies	Yes	Yes
R^2	0.0708	0.0747
Number of observations	644	644

Source: Authors' calculations using PATANAS 1994/95; PODES 1996, 2006; and IMDG 2007 Version 1.
Note: Numbers in parentheses are absolute *t*-values, using robust standard errors with village-level clusters. Education variable: 1 = household head completed high school or higher; 0 = otherwise. The dependent variable is the change in nonfarm self-employment income share; the independent variables are interacted with change in average road quality.

Table 4.11 Summary of parameter signs in select villages of Indonesia

	Per capita income growth		Nonagricultural income share		Nonfarm self-employment income share	
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)
Educ	+	+	– –	– –		
Educ_ Distance subdistrict			+ + +	+ + +	+	+ + +
Educ_Distance district	– – –	– –				
Educ_Distance province	+ + +	+ + +			– – –	– – –
Land size	n.a.		n.a.		n.a.	
Land_Distance subdistrict	n.a.		n.a.		n.a.	– –
Land_Distance district	n.a.		n.a.		n.a.	
Land_Distance province	n.a.	– –	n.a.		n.a.	
Village dummies	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.1093	0.1119	0.1004	0.1073	0.0708	0.0747
Number of observations	589	589	644	644	644	644

Source: Authors' calculations using PATANAS 1994/95, PODES 1996, 2006, and IMDG 2007 Version 1.
Note: Three signs are significant at 1 percent level. Two are significant at 5 percent level. One is significant at 10 percent level. Minus (–) means coefficient is minus and plus (+) means coefficient is plus. Blank cells: Variables are not statistically significant.
n.a. Not applicable (not included in the specifications).
Note: Education variable: 1 = household head completed high school or higher; 0 = otherwise. The independent variables are interacted with change in average road quality.

Table 4.11 summarizes the signs of our parameter estimates. First, interesting results are concentrated in education effects. In general, land does not matter in the dynamics of household income and nonagricultural transition. Second, while education augments the impact of road quality improvement (spatial connectivity) on per capita income growth, it decreases the impact on nonagricultural transition. Third, a similar contrast is observed in the role of distance to different economic centers. In the transition to nonagricultural activities among educated households, the marginal impact of an improvement in local road quality is large in locations distant from local economic centers (subdistrict capital), but in income dynamics, the impact is large in villages far from the provincial capital.

In our definition, nonagricultural activities only cover activities done by current household members. This excludes nonmembers who work in locations distant from their village (not able to commute from their village). Therefore, it is still possible that we are missing migration-linked nonagricultural transition. Instead, income growth includes agriculture-based growth, which, for example, includes improved marketing of agricultural products (for example, vegetables). In this activity, connecting to larger demand centers seems to be a driving force.

Policy discussion

This paper is intended to bridge the gap between academic studies and infrastructure planning. Previous academic studies on spatial connectivity of rural households were limited in the sense that they perceived connectivity only as access to local towns or distance from growth centers and were unable to discuss the combination of both. But in actual policy choices, public investment planners face decisions on the allocation of resources among trunk roads (which lead to economic centers) and local roads. Public investment planners also face policy choices regarding the balance between spending on education and spending on roads.

The analyses described in this paper suggest that the more educated households can raise their income with better spatial connectivity at the local level. Better-quality local roads may also improve the access of remote villages to trunk roads and thus help the more educated to engage in better job or business opportunities in the district capital (local economy) or provincial capital (larger economic center).

However, the effect on income growth is augmented both by proximity to the district center, which is significantly positive, and by distance from the provincial center, which is significantly negative. Although we cannot include it in the empirical analysis due to data limitations, this difference may be due to the market space as well as the value added of different income-generating activities. First, income-generating activities exist that focus on the market, with a district capital as the local economic center. These may include activities such as food processing with low value added (such as dried fish or chips and crackers) and marketing of staple foods. In this case, proximity to the economic center is a key, as it reduces transport-related transaction costs. However, other types of activities have a wider market area, especially catering to urban economic centers such as provincial centers. These may include higher value added goods, such as bamboo or wood products, that are sold in large urban markets. Another example is high-quality vegetables for the urban market. In this case, the added value is high enough to cover the transaction costs due to transportation, making distance from the provincial center not an obstacle, provided that it is connected to economic centers. Better road connectivity to the provincial center in the form of better local roads may give remote villages the chance to market such value added products.

In the former case, improving the trunk roads connecting villages to closer district centers is important, as is improving local roads that provide access to trunk roads. In the latter, it is important to develop the network of trunk roads that connect villages to distant economic centers, such as the provincial capital, as well as to improve local roads.

Poverty reduction strategies adopted by low-income countries, especially those in Africa, are entering a second stage in which they are becoming more growth oriented. Compared with the previous generation of strategies emphasizing the allocation of resources to primary education and health, the current generation focuses on growth strategies. Yet little is known about the combination of public investments that induces growth. This paper suggests that investing simultaneously in connecting local neighborhoods spatially with one another as well as in connecting them to distant economic centers pays off. It also suggests that investing in both higher education (high school and above) and roads is important. Although the actual approach should be country driven and country specific, such findings can add value to the next generation of growth-oriented poverty reduction strategies.

Conclusions

This paper has examined the impact of spatial connectivity on household income growth and nonagricultural income share, combining household panel data and village census data in Indonesia. Empirical results show that the impact of an improvement in road quality in the local area (positively correlated with an increase in transportation speed) on income growth and the transition to nonagricultural activities depends on the distance to economic centers and household education and landholding size. In particular, postprimary education significantly increases the benefits from an improvement in local connectivity in remote areas. Postprimary education and local road quality are complementary, increasing income growth. Therefore, the effectiveness of improved local connectivity (measured by household income growth) depends on village remoteness and initial household-level endowment.

Notes

Futoshi Yamauchi is a research fellow and Reno Dewina is a research analyst with the International Food Policy Research Institute (IFPRI); Megumi Muto is a senior economist with the Japan Bank for International Cooperation (JBIC) and Sony Sumaryanto is a senior researcher with the Indonesian Center for Agriculture Socio-Economics and Policy Studies (ICASEPS). The authors would like to thank JBIC for financial support. This study is based on a collaboration of JBICI, IFPRI, and ICASEPS.

1. 1994–95 PATANAS survey consists of two subsurveys. Income and production data are available from the second part, which contains 34 villages in six provinces excluding South Kalimantan. To merge the household panel data with spatial data on road quality constructed from PODES (1996–2006), we use the information on subdistrict, district, and province identification. In the analysis, we interact subdistrict-level road quality variables with household- and village-level variables such as landownership and distance to district center. At this stage, we cannot construct road quality data for two subdistricts in North Sulawesi, as they have missing information in PODES. When we constructed village panel data from PODES for other studies to analyze village dynamics, we had a problem in linking villages across rounds because of village divisions and mergers partly due to the decentralization process in the country. To solve this problem, we linked subdistricts and then linked villages within each subdistrict by their names. In this chapter, however, because we only use subdistrict-level information—the average proportion of asphalt roads in intervillage roads—the above problem is less important.

2. We use Epanechnikov kernel function and a default bandwidth in the application. We also have performed estimations with alternative bandwidths, but the key messages presented in this paper are almost the same.

3. We use two types of spatial connectivity indicators. First, we calculate the national and provincial road density, in terms of road distance per area, as a proxy for road network for each of seven surveyed provinces, using data in JBIC (2004) because development of both a road network within an economic region (for example, a province) as well as a route to economic centers is important for measuring spatial connectivity. The road density ranges from 0.04 in South Kalimantan province to 0.13 in North Sulawesi province. Second, we calculate indicators of speed (kilometers per minute) to reach the district or provincial center, using data on time to get there by the most common mode of transportation, as physical distance may have different implications for the connectivity to economic centers, depending on factors such as road and traffic conditions. In fact, indicators of speed are not significantly correlated with physical distance in our data.

4. The data show that manufacturing activity related to wood (including bamboo) accounts for more than 25 percent of all manufacturing activity in villages located 40–55 kilometers from the district center, while the main manufacturing activity in other areas is food processing.

5. The high-speed group includes villages where the speed (kilometers per minute) to reach the nearest district center is equal to or more than 0.56 kilometer in dry season, and the low-speed group includes other villages.

6. In our empirical setting with a small number of villages in each subdistrict, we cannot identify the effect of a change in the subdistrict-level road quality on household-level outcomes. As figure 3 shows, the effect seems to be positive for income growth and negative for nonagricultural income share. In preliminary analyses, we could not find significant effects with province-level dummies except in a few cases. Therefore, we focus on intravillage distributional effects (with village dummies controlling for price changes and village-level shocks) in our parametric estimation.

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