

# The Impact of Road Development in Rural Papua New Guinea

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Joint work with  
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# Roads and Household Welfare

- Road access can increase welfare through better access to
  - Good Markets, for buying and selling
  - Services, such as health and education
  - Labor markets
- Effects may be heterogeneous
  - Are rural roads pro-poor?
  - Some people may be harmed by increased competition
- Impact analysis can quantify these effects

# Issues with assessing impact of roads

- Investment in roads are targeted towards areas based on
  - Need
    - High (potential) growth areas with relatively poor infrastructure
  - Political favoritism
    - Burgess (2015)
- Positive correlation between welfare and road access does not imply that road access causes welfare

# A field trip

- Many roads now improved
- Villagers could very well articulate benefits of roads
  - Roads improvements made public transport possible
  - Made it easier to sell local produce



# Literature on road impacts

- Focus on variation induced by exogenous factors
  - Instrumental variables (Gibson, Rozelle 2003, Banerjee, Duflo, Qianx. 2012)
  - Gibson and Rozelle use the time of connection to the national highway as exogenous variation for PNG
- Approximate experiment by finding control areas that are very similar ex-ante but did not receive a road investment
  - Difference in difference with matching (Mu, vd Walle 2011, Lokshin, Yemtsov 2005)
- Focus on changes by regions
  - Dynamic analysis based on panel data (Khandker et al 2009,2011)
  - Corrects for road placement based on time invariant regional characteristics

# Literature on road impacts

- Generally confirms positive effects on reduction in poverty rates
- For PNG, Gibson and Rozelle estimated that reduction in travel time by
  - one hour would increase per capita household consumption by 1.4% to 5.3%.
  - two hours would lead to an overall reduction in poverty between 5.8% and 11.8%.

# This study

- Builds on the work by Gibson and Rozelle (2003) who used the 1996 PNGHS.
- We use
  - 1996 and 2009/10 household surveys
  - Maps of roads infrastructure from around both years
  - Control variables (climate, topography)
- To analyze the impact of road quality over this period on household welfare
  - No new road construction over this period, so we cannot identify its effect.

# This study

- Uses an approach similar to panel data models but without panel data because we never observe the same village in the two household surveys
- We can do so because we have road access variables for all villages in both years
- This allows us
  - to correct for endogeneity of roads resulting from time invariant regional factors
  - to use a much richer set of road variables than what is usually available in household surveys



# Outline

- Data and descriptive analysis
- Model
- Estimates of road impact

# Data

- Household survey 1:
  - The 1996 PNGHS, a nationally representative household survey with rural 73 census units and 830 rural households.
- Household survey 2:
  - The 2009/10 HIES, a nationally representative household survey with 125 rural clusters and 2208 rural households.
  - Thanks to John Gibson we have GPS coordinates for each household, so we can put the households themselves on a map
- Census data from 2000.
  - We can link census units (clusters of varying size, usually around 100 households) to those in the two household surveys.
  - we can put census units on a map (as points).
- Geoclimatic data: elevation, gradients, rainfall, land cover, inundation occurring (mostly from PNGRIS, partly from HIES 09/10)

# Descriptives

Table 1: Welfare indicators included in 1996 and 2009/2010 household surveys

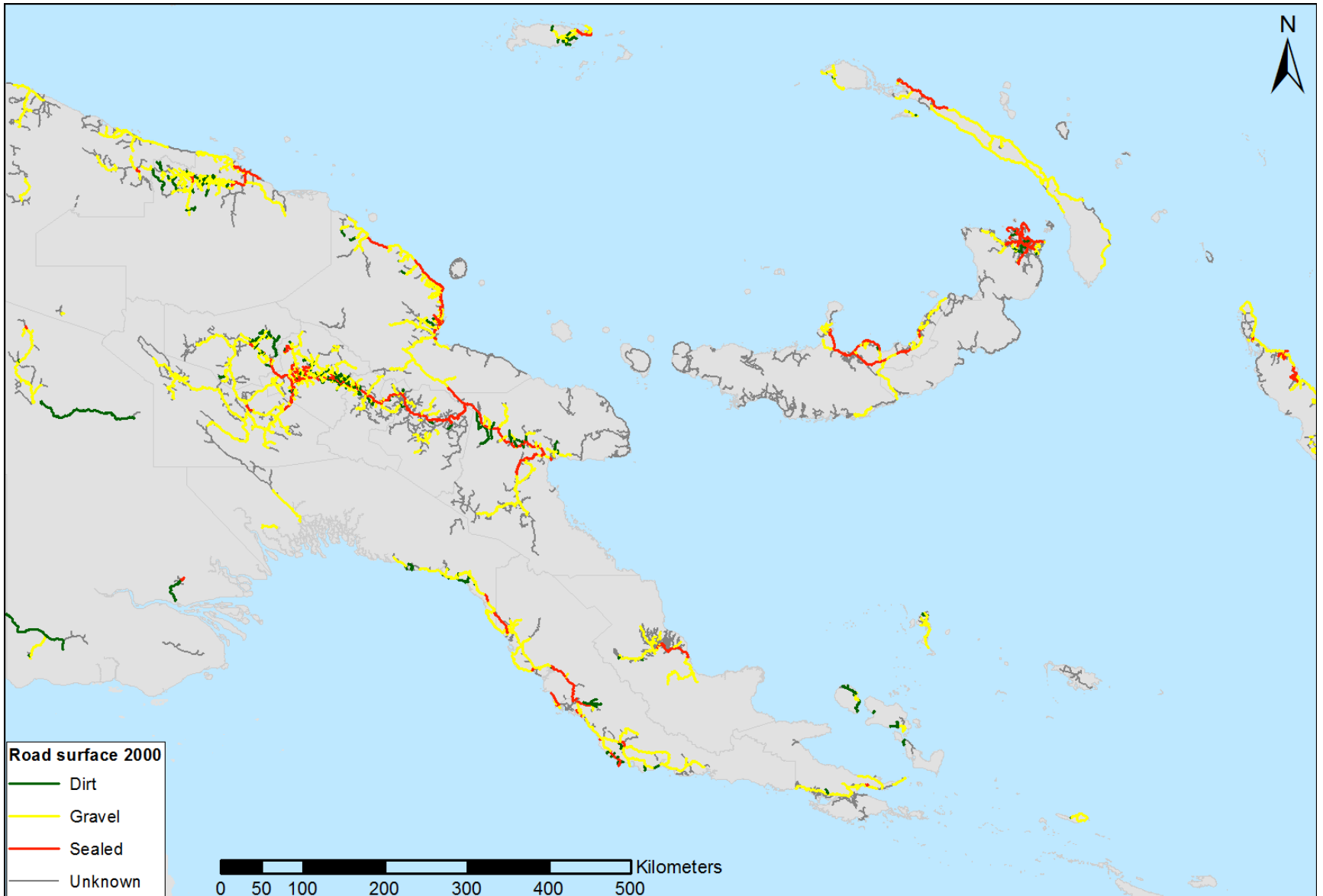
	PNGHS 1996			HIES 2009/10		
	Mean	Std. Err.	N	Mean	Std. Err.	N
Age	22.47	0.415	2869	23.09	0.376	4931
Going to school (for school-aged children)	0.375	0.052	633	0.515	0.048	878
How long to get to school (minutes)	42.12	5.084	401	33.75	5.108	1079
Ever been to school (if at least 12 years old)	0.466	0.047	1930	0.591	0.030	3431
Literacy (if at least 12 years old)	0.348	0.043	1930	0.401	0.028	3431
Short of Food	0.405	0.055	469			
Electricity	0.037	0.020	469	0.095	0.022	1052
Access to safe drinking water	0.198	0.048	469	0.249	0.042	1042
Good cooking fuel	0.019	0.014	469	0.070	0.010	1052
Have own toilet	0.931	0.020	468	0.902	0.017	1014
HH Size	6.229	0.266	467	4.521	0.099	1052
Number of rooms	3.221	0.195	467	2.232	0.086	1052
Floor Area	34.27	1.936	467	36.47	1.755	1052
Headcount Poverty*	0.395	0.046		0.413	0.034	

\* Values from technical report on PNG poverty profile, John Gibson 2012

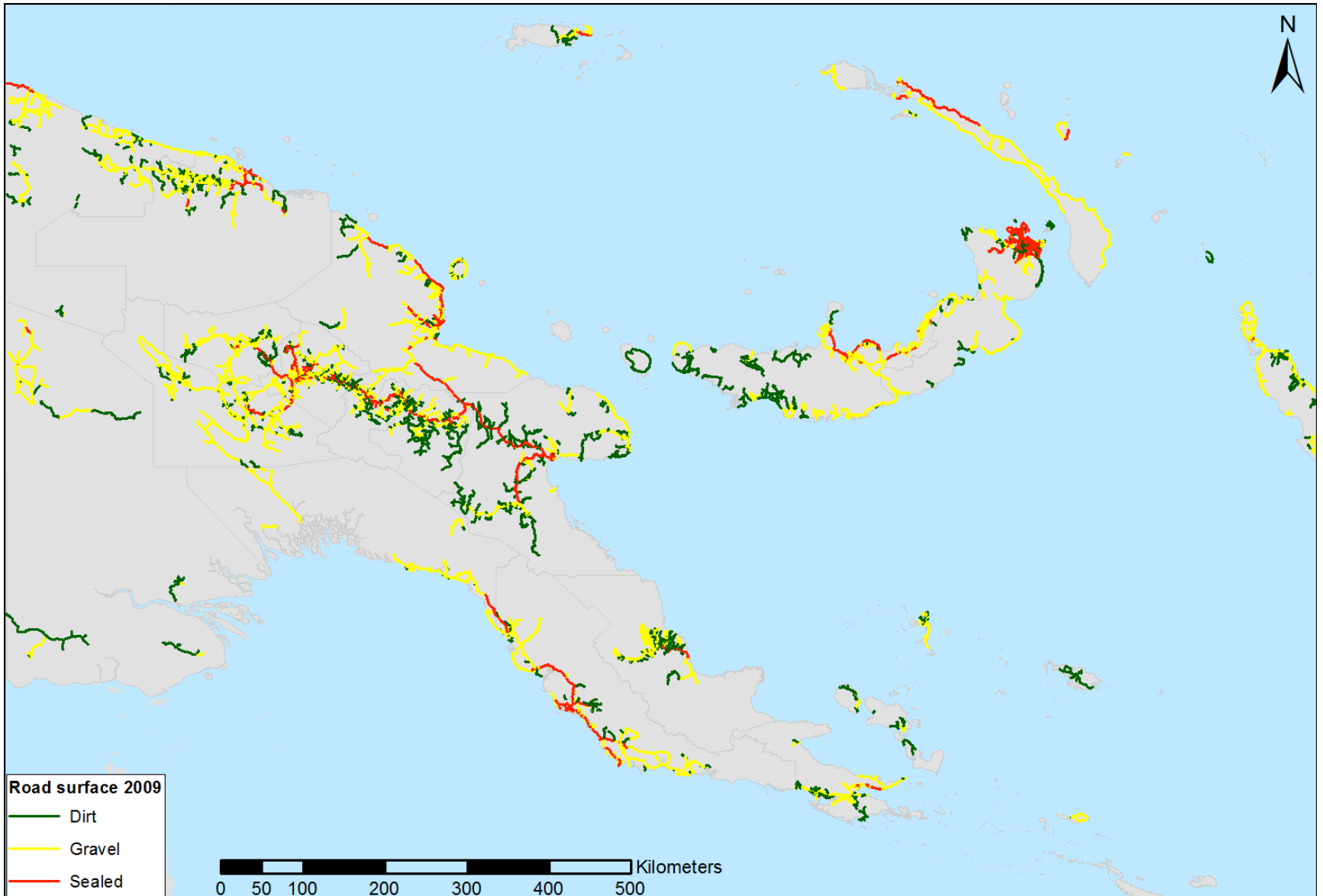
# Roads data

- Road asset management data
  - A detailed roadmap from 2009, containing 25,649 km of road,
  - Contains information per road stretch on surface type (sealed, gravel, dirt), road type (highway, national road, provincial road) and condition (good, fair, poor).
- Road data for 2000 combined from two sources that contain road quality info from the initial 1999/2001 RAMS survey:
  - The national road network (ca. 6400 km)
    - Contains information on surface type and condition.
  - The provincial road network (ca. 7400 km)
    - Contains surface type and predictors of condition (roughness index, no of potholes, etc.), used to estimate condition
  - Kindly provided by Bryant Allen (Australian National University)
  - Missing stretches received same quality as 2009 road map

# Roads 2000



# Roads 2009



# Roads data

Surface	Condition	2010 (NSO data)		2000 (matched)	
		Total length (km)	%	Total length (km)	%
Dirt	Poor	4367	17%	4765	19%
Gravel	Poor	5762	22%	7382	29%
Sealed	Poor	361	1%	423	2%
Dirt	Fair	3699	14%	2525	10%
Gravel	Fair	7364	29%	5374	21%
Sealed	Fair	1048	4%	1320	5%
Dirt	Good	168	1%	342	1%
Gravel	Good	1111	4%	2477	10%
Sealed	Good	1770	7%	1041	4%
<i>total</i>		<i>25,649</i>	<i>100%</i>	<i>25,649</i>	<i>100%</i>

# Transition matrices

	Sealed 09	Gravel 09	Earth 09
Sealed 01	1886.6	238.52	96.59
Gravel 01	708.3	6909.15	858.28
Earth 01	28.08	316.23	1220.91

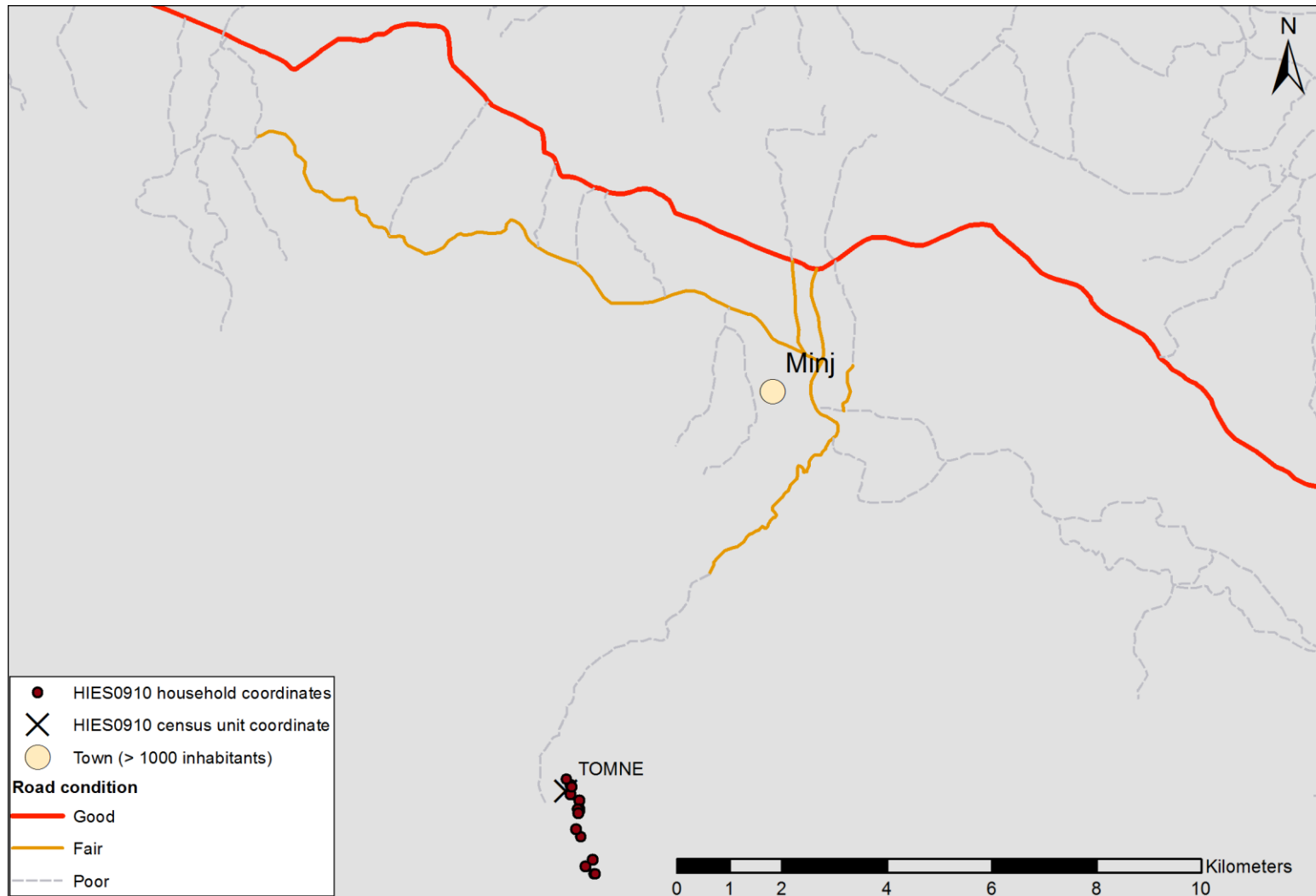
	Good 09	Fair 09	Poor 09
Good 01	1111.94	1683.37	708.47
Fair 01	960.44	1005.52	782.77
Poor 01	475.81	3118.39	2415.95



# Combining the data

- Survey locations placed on map to calculate *network* distance to nearest town (> 1000 people)
  - Distinguishing distances over different road types and road conditions
  - We also calculate walking distance from census unit to nearest road (max. 15 km)
- Same calculations for 1996 and 2009/10 HIES

# Combining the data



# Model

$$y_{ijpt} = \beta R_{jpt} + \gamma X_{ijpt} + \nu_p + \mu_j + \tau_t + \varepsilon_{ijpt},$$

$$E^*(\mu_j | R_{jp,00}, R_{jp,09}) = \delta + \delta_{00} R_{jp,00} + \delta_{09} R_{jp,09},$$

For walking distance to road we estimate a within estimator for 2009 (village fixed effects)

$$y_{ij,09} = \rho d_{ij,09} + \gamma X_{ij,09} + \mu_j + \varepsilon_{ij}.$$

# Model specification

- Modelling road access

$$\beta_1(\textit{km of sealed road}) + \beta_2(\textit{km of gravel road}) \\ + \beta_3(\textit{km of road})$$

- Or

$$\beta_1(\textit{share of sealed road}) + \beta_2(\textit{share of gravel road}) + \log(\textit{km of road})$$

# Results linear distance

Table containing the third specification (which includes CRE terms and household covariates) for all five outcomes, using absolute distance

Outcome	ln(consumption)	poor	Having a good roof	Owning farm animals	Ratio of children going to school
Earth to sealed	0.0168** (0.007)	-0.0061 (0.004)	0.0105*** (0.004)	-0.0173*** (0.006)	0.0013 (0.005)
Earth to gravel	0.0015 (0.005)	-0.0001 (0.003)	0.0063*** (0.002)	-0.0069* (0.004)	-0.0042 (0.003)
Gravel to sealed	0.0153** (0.007)	-0.0061 (0.004)	0.0041 (0.003)	-0.0103** (0.005)	0.0055 (0.004)
Total dist. (earth)	0.0170*** (0.005)	-0.0051 (0.003)	0.0039* (0.002)	0.0070* (0.004)	0.0016 (0.003)
Dist. to nearest road	0.0256* (0.015)	-0.0193** (0.009)	-0.0286*** (0.006)	0.0109 (0.012)	-0.0079 (0.007)
R-sqr	0.289	0.201	0.478	0.278	0.200
CUs	155	155	155	155	155
Households	2067	2142	2228	2103	1474
p-value CRE	0.000	0.052	0.002	0.090	0.124

# Results log distance and shares

Outcome	ln(consumption)	poor	Having a good roof	Owning farm animals	Ratio of children going to school
Earth to sealed	0.4769** (0.222)	-0.1192 (0.145)	0.2333** (0.094)	-0.2792* (0.164)	0.0275 (0.112)
Earth to gravel	0.0928 (0.178)	0.0780 (0.119)	0.1423* (0.084)	-0.1079 (0.150)	-0.1762* (0.097)
Gravel to sealed	0.3841** (0.181)	-0.1972* (0.109)	0.0910 (0.077)	-0.1713 (0.113)	0.2037** (0.100)
ln(total dist.)	-0.1222*** (0.030)	0.0688*** (0.017)	-0.0196 (0.018)	0.0338 (0.021)	-0.0103 (0.016)
ln(dist. to nearest road)	0.0073 (0.016)	-0.0096 (0.009)	-0.0186*** (0.007)	-0.0142 (0.010)	-0.0159** (0.008)
R-sqr	0.291	0.207	0.472	0.276	0.198
CUs	155	155	155	155	155
Households	2067	2142	2228	2103	1474
p-value CRE	0.000	0.004	0.154	0.056	0.632

Sample	Non-poor	Poor	No farm animals	Household owns farm animals	Average education < 6 years	Average education ≥ 6 years
Earth to sealed	0.4117*** (0.124)	0.1699 (0.159)	0.1639 (0.343)	0.4763* (0.277)	0.6228** (0.254)	0.1039 (0.247)
Earth to gravel	0.2415* (0.127)	-0.0219 (0.147)	0.2019 (0.330)	0.1466 (0.187)	0.1166 (0.193)	0.0767 (0.191)
Gravel to sealed	0.1702* (0.102)	0.1918 (0.148)	-0.0380 (0.208)	0.3297 (0.257)	0.5061** (0.208)	0.0272 (0.212)
ln(total dist.)	-0.0520** (0.020)	-0.0201 (0.029)	-0.1712*** (0.039)	-0.1087*** (0.035)	-0.0983*** (0.037)	-0.1996*** (0.036)
ln(dist. to nearest road)	-0.0051 (0.010)	0.0118 (0.011)	-0.0187 (0.022)	0.0270 (0.019)	0.0135 (0.019)	-0.0178 (0.017)
R-sqr	0.182	0.204	0.333	0.306	0.311	0.309
CUs	155	155	155	155	155	155
Households	1324	743	756	1191	1344	723
p-value het. effects	0.000		0.029		0.058	

# Results road access

- Adding condition variables gives strange results
  - Coefficients do not point in particular direction
  - Possibly due to multicollinearity. Condition assessment and surface type are correlated.
  - Possibly measurement error: road condition not measured consistently between provinces and over time.



# Distance to nearest road (2009)

Outcome	ln(consumption)	poor	Having a good roof	Owning farm animals	Ratio of children going to school	p.c. hours in subs. farming	Ratio of subs. famers
ln(dist. road)	-0.0209	0.0106	-0.0270***	0.0024	-0.0250***	0.0170	0.0119**
(OLS)	(0.018)	(0.010)	(0.009)	(0.010)	(0.007)	(0.291)	(0.005)
ln(dist. road)	-0.0330	0.0371***	-0.0249**	-0.0114	-0.0164	-0.4091	0.0040
(Village FE)	(0.022)	(0.014)	(0.010)	(0.013)	(0.010)	(0.376)	(0.008)

# Heterogeneous treatment effects

- Dep variable  $\ln(\text{real consumption})$

Sample	Non-poor	Poor	No farm animals	Household owns farm animals	Average education < 6 years	Average education = 6 years
Earth to sealed	0.4117*** (0.124)	0.1699 (0.159)	0.1639 (0.343)	0.4763* (0.277)	0.6228** (0.254)	0.1039 (0.247)
Earth to gravel	0.2415* (0.127)	-0.0219 (0.147)	0.2019 (0.330)	0.1466 (0.187)	0.1166 (0.193)	0.0767 (0.191)
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$\ln(\text{total dist.})$	-0.0520** (0.020)	-0.0201 (0.029)	-0.1712*** (0.039)	-0.1087*** (0.035)	-0.0983*** (0.037)	-0.1996*** (0.036)
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R-sqr	0.182	0.204	0.333	0.306	0.311	0.309
CUs	155	155	155	155	155	155
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# Conclusion

- Extended the work by Gibson and Rozelle to assess effects of changes in road condition between 1996 and 2009
  - Clear effects as expected on consumption and having a good roof
    - Heterogeneity analysis indicates that non-poor households profit more than poor households.
  - Having good road reduces less farm animals.  
Working in town?
  - No clear effects on schooling

# Transition matrices

	Sealed good 09	Sealed fair 09	Sealed poor 09	Gravel good 09	Gravel fair 09	Gravel poor 09	Earth good 09	Earth fair 09	Earth poor 09
Sealed good 01	617.71	186.55	37.8	15.21	41.02	23.19	0	15.73	1.31
Sealed fair 01	509.57	240.29	69.14	8.24	62.93	53.93	0	0	6.44
Sealed poor 01	96.46	61.85	67.23	8.21	21.26	4.53	0	19.69	53.42
Gravel good 01	257.51	71	19.66	219.52	1166.08	551.32	0	18.03	31.16
Gravel fair 01	153.64	65.81	47.17	288.99	566.28	564.97	0	32.45	14.35
Gravel poor 01	41.19	33.1	19.22	268.13	1804.55	1479.31	28.76	498.45	235.08
Earth good 01	1.99	0	0	0	27.55	11.48	0	157.41	32.55
Earth fair 01	0	4.64	3.3	0	0	.89	0	33.12	22.58
Earth poor 01	10.32	7.83	0	0	178.35	97.96	22.74	493.31	459.2