Journal of Transport Economics and Policy, Volume 54, Part 4, October 2020, pp. 267–288

High-speed Rail, Urbanisation, and Housing Affordability

Evidence from the Shinkansen System

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Abstract

We re-examine the economic consequences of the Shinkansen in Japan from 1964 to 2010. We examine, separately and jointly, two different episodes in Japanese economic history. We construct a prefecture-level data set for Japan with macroeconomic and socio-demographic variables, as well as data on the opening and operation of each of 10 Shinkansen lines. We provide evidence that high-speed rail has a negative impact on prefecture land prices and is neutral with respect to economic growth, even as it spurs growth around rail stations, induces urban sprawl, increases housing affordability, and reduces overall urban density.

Final version: October 2020

1.0 Introduction

High-speed rail has become the vogue transportation infrastructure investment in the world today. China leads the way with an ambitious programme of trunk routes, including plans for long-range high-speed rail to Europe. Projects in India, Malaysia, Thailand, Morocco, and the USA are underway. While there are many reasons to build high-speed rail — an alternative to highway or airport infrastructure, cleaner transportation, convenience, and the replacement of existing congested rail service — an oft-heard argument is that adopting high-speed rail will lead to greater economic growth and job creation. Less heard, but equally important, is the logic that led to the first major high-speed rail line, the Tokaido line in Japan: that of easing congestion and improving commuting in large urban centres. We revisit the longest operating high-speed rail system, the Japanese Shinkansen, in a study of land prices, population dispersion, and GDP growth, and draw implications for economies and affordable housing for some of the world's most dense and least affordable cities.

The economic impact of high-speed rail (HSR) has been analysed and critiqued by many researchers. The evidence about the socio-economic effect of HSR is mixed. For example, Sands (1993) found that HSR contributed to economic development in Japan, particularly around HSR stations, and that regions served by HSR experienced higher employment and population growth rates compared to unserved regions. Mohino *et al.* (2019) found that HSR contributed to higher population growth in small cities in France and Spain due to migration. However, Banister and Berechman (2000) found that the presence of HSR in French towns does not automatically translate into economic benefits. Other studies such as Whitelegg *et al.* (1993), Spiekermann and Wegener (1994), and more recently Chen and Vickerman (2017), found that HSR tends to favour larger cities at the terminus of the HSR line at the expense of intermediate cities, particularly those that were bypassed by the HSR. Bazin *et al.* (2013), in a study of HSR in Eastern Europe, also found that the mere existence of HSR is insufficient to accelerate urban dynamics; however, if, in their terms, a smaller city has tourism potential, then with appropriate policy, HSR can serve as a catalyst for tourism development.[1]

The results of the research cited above are mixed, but weakly suggest that HSR improves both the connectivity of markets and the cost of business travel, and is therefore a causal factor in increased economic growth. However, the relationship between housing affordability and HSR has not been well studied. This presents an identification problem in the analysis of HSR-induced economic growth and of HSR-induced urban sprawl. Although Baum-Snow's (2007) study of highways and urban sprawl is instructive with respect to population distribution, HSR differs from other transportation infrastructure in two ways: it transforms far-outlying regions into reasonable commuting time locations; and it typically carries only passengers and not freight. Analysing HSR's economic impact requires separating out that part which is related to induced economic growth

[1] See also Boopen (2006), Givoni (2006), De Rus and Nombela (2007), Gourvish (2010), Abalate and Bel (2012), and Preston (2012). Individual country studies include Banerjee *et al.* (2012) and Qin (2017) on China, Haynes (1997) and Sasaki *et al.* (1997) on Japan, and Gutierrez *et al.* (1996), Vickerman (1997), Gutierrez (2001), Puga (2002), and Barron *et al.* (2009) on Europe.

in the region surrounding the rail corridor, and that which is related to lower-cost commuting.

More generally, transportation infrastructure and economic growth studies must deal with a related identification problem. Namely, is the transportation infrastructure — in this case HSR — caused by regional economic growth or is it a causal factor of it? Fishlow's (1965) seminal work on railroads in the USA found that the rail lines were laid down in response to and not because of westward population migration, and therefore were not causal factors in economic growth.

Canning and Fay (1993) addressed this identification problem with a cross-country analysis of rates of return to rail and road construction, and found them to be highly variable and only somewhat related to the degree and vintage of the industrial sector affected. Rephann and Isserman (1994) found similar results for highway infrastructure in West Virginia. Atack *et al.* (2010) revisited Fishlow using an instrumental variables analysis, and concluded that about half of the urbanisation, and economic growth, was attributable to the railroad construction. Faber's (2014) identification strategy was a hypothetical least-cost spanning tree network in a study of Chinese highways; and Donaldson and Hornbeck (2016) addressed identification with a Ricardian trade 'market access' approach measuring the effect of the railway system on agricultural land values in America.

Nevertheless, these and other quasi-experimental control observation studies do not address the question of causality between economic growth, urban sprawl, and the newer transportation technology: HSR.[2] The strategy herein is related to Canning and Fay (1993) in that it employs variation in the treatment (HSR) over all Japanese prefectures and over time to achieve identification.

Specifically, we use a panel comprised of all prefectures in Japan to exploit the unique history of the Shinkansen. The HSR system in Japan grew, on average, with new lines and their extensions every four years, between 1964 and 2004. This spans a period of rapid growth and a period of stagnation in the Japanese economy. In addition, through the time period of our study, there were many prefectures that did not have a Shinkansen line operating within their borders and many that had a Shinkansen line during only part of the period. By examining the entire system as it evolved over time, including non-Shinkansen prefectures as controls, capturing different economic regimes both separately and jointly, and analysing the difference between both real estate values and economic growth from their expected values due to other factors, we are able to solve the identification problem.

In post-World War II Japan, many prefectures were growing rapidly, but most were not early beneficiaries of HSR. This was because the initial system was designed to be an alternative to congestion on certain city pairs (for example, Tokyo–Nagoya–Osaka). In addition, some prefectures along the rail lines were predominately rural at the time of HSR introduction (for example, Shizuoka), and others, though they were industrial and growing rapidly, were not favourably placed between the target cities (for example, Chiba). Consequently, the placement of HSR lines was not entirely driven by past and expected economic growth.

[2]See also Martin (1998), Reitvelt *et al.* (2001), Graham (2007), Elhorst and Oosterhaven (2008), Preston and Wall (2008), Graham and Melo (2010), and Preston (2012) on agglomeration effects,

By studying the entire evolution of the Shinkansen, this work adds to the body of knowledge on HSR with respect to economic growth and housing affordability. We created a unique set of data with which to ask the above questions, and thus benefit from more extensive data and more treatments than previous HSR studies of Japan such as those of Hirota (1985), Nakamura and Ueda (1989), and Chen and Abreau (2014). The article proceeds with a brief history of the Japanese Shinkansen, followed by two simple models that can incorporate the impact of HSR, a description of the data, and the results.

2.0 The Shinkansen

At the end of World War II, much of Japan's infrastructure and capital stock were in shambles. Roderick Smith described it as follows: 'When the Occupational forces arrived in Japan in 1945 they were stunned to see the extent of urban destruction caused by the bombing . . . Resources had been absorbed by the war effort with the result that both equipment and infrastructure were in a grievous state.' A key to recovery was rebuilding and upgrading the transportation system. The nationalised railway company, JNR, added electrification, dual tracks, and other upgrades to the system; in particular, it rebuilt the Tokaido line linking the populous metropolises of Tokyo and Osaka.

However, by the mid-1950s the rail system was reaching capacity. Although the general consensus was that road and air travel would replace rail as the dominant transportation mode, executives at JNR made the case for an all-passenger, high-speed rail line. In 1958, a government panel was formed to study the issue and it recommended the replacement of the existing Tokaido line with an HSR to expand capacity on the corridor, to relieve commuter congestion in Tokyo, and to facilitate economic growth.[3]

Construction began in 1959 and was completed in 1964 in time for the opening of the Olympic Games. Construction of the rail line was financed through a bond issue and a World Bank loan. JNR was able to achieve financial and governmental support by demonstrating that it was using established high-speed rail technology through the engineering expertise gained from the Asia Express, a rail line they built and operated from 1934 to 1943 in the colony of Manchuko that had been carved out of the Chinese region of Manchuria.[4]

While the objective of the Tokaido line was to relieve pressure on an overcrowded railway system between Tokyo, Osaka, and Nagoya, it was its potential as a relief valve for crowded conditions in Tokyo, through a reduction in the cost of commuting from outlying villages and cities, which secured final approval by the government. The Tokaido line has often been cited as one of the most successful HSR lines for its roles in both reducing congestion and generating increased economic growth.[5]

Subsequent to the introduction of the Tokaido line, Japan built the Sanyo line linking Osaka to Fukuoka, completed in 1972 and extended in 1975. The Tohoku line was completed in four segments: 1982, 1985, 1991, and 2002. The Joetsu line opened in 1982 and the Hokaruku opened in 1997. The last line represented in our data set is the

[3]See, for example, Wakuda (1997) and Smith (2003) for a description of the infrastructure issues and decisions.
[4]See Jackson (1913) and Young (1998) for a description of the Japanese railway in Manchuria.
[5]See, for example, Matsuda (1993), Okada (1994), Givoni (2006), and Gourvish (2010).

Kyushu line, which opened in 2004. This construction ultimately linked most large Japanese cities into the Shinkansen network, although the largest and most prosperous prefectures were not always on the routes of the rail lines. Upgrades and improvements to the network have continued, and new technologies have been developed and introduced.

Japan Railways Group (JRG), the operator of the Shinkansen system, was formed in 1987 from the previous government-owned Japanese National Railways (JNR). Although they have not always been profitable, the constituent companies benefited from a 14 trillion yen debt taken off JNR's books prior to the formation of JRG. It is worth noting that efficiency gains, as studied in Smith *et al*. (2018) and others focusing on the European experience, could have lowered the costs of high-speed rail transport in Japan. While we would expect the impact to be the same as found in our results, we would also expect them to be of a greater magnitude.

The expansion of this system provides a backdrop for counterfactuals in that new lines were added on average every four years, and in that there were many prefectures, including ones containing large cities, that did not have HSR during at least part of the period from 1964 to 2010.[6]

3.0 Theoretical Construct

To organise the empirical analysis and develop testable hypotheses, we propose two simple models: one of HSR-induced GDP growth; and one of HSR-induced housing location choice. These models embody all of the economic behaviour we expect to see or refute in our analysis, and therefore they provide the appropriate guide for the regression equations and empirical identification.

For GDP, we assume a standard Cobb–Douglas production function for each prefecture i, with total output, Y_i:

$$Y_i = A_i K_i^{\alpha} L_i^{(1-\alpha)} \Pi_{j=1}^{n} T_{i,j}^{\gamma(i,j)}, \tag{1}$$

where Y is income, A is TFP, K is the capital stock, L is labour, and T is a vector of variables indexed by j describing the impact of other factors, including transportation infrastructure on the production of Y.

Dividing by L and taking logs yields a per-capita GDP equation:

$$y_i = a_i + \alpha\, log\left(\frac{K_i}{L_i}\right) + \Sigma_j \gamma_{i,j}\, log(T_{i,j}). \tag{2}$$

Taking time differences yields a per-capita GDP growth equation:

$$y_i(t) - y_i(t-1) = (a_i(t) - a_i(t-1)) + \alpha\left(log\left(\frac{K_i(t)}{L_i(t)}\right) - log\left(\frac{K_i(t-1)}{L_i(t-1)}\right)\right) + \Sigma_j \gamma_{i,j}(log(T_{i,j}(t)) - log(T_{i,j}(t-1))) + \beta Shin_{i,j}(a_i(t) - a_i(t-1)). \tag{3}$$

[6]A map of prefectures and a map of the Shinkansen lines is found in Appendix B.

The first term $(a(t) - a(t-1))$ picks up technological and process change by prefecture unrelated to transportation infrastructure, and will be captured by year/prefecture fixed effects. The second term captures the standard production structure, and the third captures the idiosyncratic aspects of prefectures. It is in the third term that such factors as the presence of a seaport, the presence of HSR, the introduction of HSR, and pre-existing urbanisation would impact overall and per capita output. Equation (3) is the basic equation of analysis for GDP growth rates. The last term is shown separately from the others in T to highlight the presence of the Shinkansen (Shin = 1) in changing the average growth rate.

From equation (1) we also have a regression on the level of GDP by prefecture:

$$Log(Y_i) = Log(A_i) + \alpha Log(K_i) + (1-\alpha)Log(L_i) + \Sigma_j \gamma_{i,j} Log(T_{i,j}) + \beta Shin_{i,j}. \quad (4)$$

From equation (4) we are able to pick up the instantaneous impact and the lagged impact of the introduction of a Shinkansen through the significance or lack thereof of the coefficients for the fixed effects representing these events. Since the presence of the Shinkansen could (perhaps with a lag) increase the wealth or employment and therefore the productive capacity of the prefecture without affecting GDP growth rates, we use equation (4) to examine this possibility.

For both equations (3) and (4), the Shin variable is modelled as a discrete instantaneous change, and as a lagged change. These equations allow us to test the following hypotheses with H1a addressing Fishlow's critique, and H1b providing further evidence on the GDP inducing, or lack thereof, of Japan's Shinkansen system:

- H1a: Prefectures with a Shinkansen line will have relatively higher GDP and/or GDP growth rates than other comparable prefectures.
- H1b: Prefectures with a Shinkansen line will have relatively higher GDP and/or GDP growth during the years the prefecture had a Shinkansen line compared to the years it did not.

If H1a and H1b are both empirically verified, then one can conclude that economic growth is driving the placement of the HSR line. If H1b is verified but H1a is not, then one can conclude that HSR is generating economic growth over and above that which would otherwise be present. If HSR does generate higher GDP and/or higher GDP growth rates, then we would expect land to become more valuable in newly opened areas, but not less valuable in city centres served by the new rail line.

Alternatively, if HSR did not induce higher economic growth (both H1a and H1b rejected by the data), then the incremental demand for commercial space and housing for a newly employed labour force would be absent. Even though land prices in prefectures that are now within commuting distance from the city centre will rise, particularly near HSR stations, in general land prices in the wider urban region ought to fall below that expected absent HSR. This is because HSR increases the amount of land available in the viable geography of the city without an aggregate rightward shift in the demand curve due to an HSR-induced income effect.

Since the empirical analysis of equations (3) and (4) failed to find an impact on GDP nor on GDP growth rates, we structure the analysis of land prices under that assumption. That is, conditioned on the β in the analysis of GDP impacts being insignificant, we specify our regressions to be consistent with a simple location choice model embodying a utility function that is decreasing in commuting time. Let:

$$U = U(I, C, R). \tag{5}$$

Be the utility function with $\partial U/\partial I > 0$, $\partial U/\partial C < 0$, and $\partial U/\partial R > 0$, where I is individual income, C is commuting transportation costs inclusive of the value of time, and R is defined as a vector of the amenities in the neighbourhood of the worker's home. For any given income, job location, and pair of potential residence locations (1,2), if $C_1 < C_2$ and $R_1 \geqslant R_2$, then the worker resides in location 1. Since employment opportunities are also spatially distributed, it is assumed, for the sake of simplicity, that this was a factor in the individual represented by equation (5)'s employment choice. The focus here is the impact of changes in C due to the introduction of new passenger transportation infrastructure.

The worker then maximises U over the set of possible domicile locations. Location j is chosen whenever $U(I, C_j, R_j) > U(I, C_i, R_i)$ for all $i \neq j$. We abstract here from the fact that the introduction of the Shinkansen could provide new job opportunities such that I increases along the line and is higher than that of the worker's current income.

The presence of the Shinkansen in proximity to location j lowers the cost C_j in the value of the time spent commuting from that location and, depending on the fare schedule and subsidies, may lower it absolutely. Then: If $|R_j - R_i|$ is sufficiently small (that is, the neighbourhood amenities are approximately the same), then there exists a commuting cost C_j such that $U(I, C_j, R_j) > U(I, C_i, R_i)$.

This is an important point because it highlights that C is a policy lever that can be used to make housing affordable, which was previously not considered affordable because of commuting costs. This is the housing affordability argument in JNR's claim for the Tokaido Shinkansen when seeking approval to proceed with the project.

With income being the basis for the demand for land and P defined as a standardised price of land, then we can write:

$$P_i = g(Y_i). \tag{6}$$

Linearising g yields equations similar to (3) and (4) with P as the dependent variable. To capture the effect on land prices due to HSR-induced commuter migration, we formulate our hypothesis conditioned on the coefficients on Shin in equations (3) and (4) being insignificant as follows:

- H2: Prefectures with Shinkansen present will have lower land prices than non-Shinkansen prefectures after conditioning on all other factors.

4.0 The Data

The sources for our data are: the Cabinet Office, Japan[7] for GDP data; a database constructed by Kyoji Fukao and Ximing Yue (2000)[5] for public and private capital stock; and a data set constructed by the authors for the fixed effects on airports, on

[7] We thank Saito Yukiko and Makoto Hazama for their invaluable help in translating the GDP data pages from Japanese to English. Land price data is available for download from https://tochidai.info.

seaports, on prefectures containing the final terminus, and on the penultimate prefecture of a Shinkansen line. The balance of the data employed in the economic growth regressions is from the Statistics Bureau of the Ministry of Internal Affairs and Communications, Japan. GDP data are from 1955 to 2010, with 2010 being the terminal year for the data set.

Data on land prices are from the Ministry of Land, Infrastructure, Transport and Tourism, Japan. The digitised data is available from 1983.[6] Therefore, we investigate the effect of the Shinkansen on land prices only for the sub-period 1983–2010.

GDP data for each prefecture were matched with corresponding data on economic variables, population, population densities, and public and private capital stock. Data on Shinkansen lines were coded for each prefecture for each year as 0 or 1, where 1 signified that the prefecture had an operational Shinkansen line for at least part of the year. If a prefecture had more than one named Shinkansen line, it was still coded as 1. Nominal GDP numbers were converted to real GDP numbers by dividing Japan's national CPI index.

To account for different regimes in the Japanese economy corresponding to years of rapid growth and years of stagnation, we segmented the data set. Further analysis was performed on the two time periods 1955–97 and 1998–2010. The first period corresponds to a high growth period in Japan, while the latter period is one of very low to negative growth. The analyses described below are for varying time periods depending on data availability and the above criteria. The GDP analyses begins in 1955, prior to the first Shinkansen line operating, while other analyses focus on years subsequent to 1964 — the year of the introduction of the Tokaido line.

5.0 Empirical Results

5.1 Estimation

All of the regressions are on panel data with the exception of the Probit model. The time frames for the regressions vary with available data. For some regressions the data is segmented by fast growth and slow growth periods in Japan. The panel consists of each of the 47 prefectures in Japan. As these were fixed and did not change during our sample frame, the asymptotic properties of the estimators run across time rather than across the heterogeneity of the panels. To eliminate the heterogeneity-induced endogeneity of the regressors in a model where some of the regressors are time-invariant, the estimation strategy is to use generalised least squares with clustered robust standard errors, where the clusters were by prefecture. For each set of regressions, robustness was examined by running the models with and without the prefecture fixed effects. All of the regressions accounted for clustered standard errors along the longitudinal axis (prefectures).

5.2 Economic growth

The first set of regressions investigates the impact of high-speed rail infrastructure on rates of economic growth at the prefecture level. While important in and of itself, it is also an essential step in assessing how HSR affects housing affordability. If HSR were to induce faster economic growth (hypothesis H1b), then land prices would reflect both in-migration due to this economic stimulus as well as in-migration by commuters previously living in cities further down the rail line. On the other hand, if HSR is not economic growth-inducing (hypothesis H1a and rejection of H1b, or rejection of both), then although in some locations, particularly those near rail stations, it would spur increases in land prices, in general, a larger amount of land will be available for the residential market and the impact on aggregate land prices would be either ambiguous or negative. The data employed are from 1955 to 1995, a period of rapid growth throughout Japan and a period for which measures exist of public and private capital stock by prefecture.

The results for the change in real GDP by prefecture, both in the aggregate and per capita, are revealing (Tables 1 and 2). The coefficient on private capital is significant and positive, as expected. Investment increased the rate of growth of GDP. However, increases in population (the potential labour force) had the opposite effect. Moreover, the presence of a Shinkansen was also associated with a decline in prefecture GDP growth rates — a rejection of the H1 hypotheses.

The original hypothesis was that HSR either increased GDP growth rates or had no effect. The empirical result was a significant negative coefficient on the Shinkansen variable.

Table 1
ΔLn(GDP) By Prefecture (1955–95)

	(1)	(2)	(3)	(4)
ΔLn(Population)	−0.337***	−0.273***	−0.337***	−0.281***
	(0.061)	(0.056)	(0.063)	(0.059)
ΔLn(Private *K*)	0.893***	0.927***	0.971***	0.960***
	(0.034)	(0.034)	(0.036)	(0.036)
ΔLn(Public *K*)	−0.115***	−0.108***	−0.119***	−0.109***
	(0.024)	(0.023)	(0.024)	(0.023)
Shinkansen	−0.024***	−0.013***		
	(0.004)	(0.002)		
Seaport	−0.038***	−0.005**	−0.047***	−0.007**
	(0.009)	(0.002)	(0.0065)	(0.003)
Shin Terminus Pref.		0.003		0.001
		(0.003)		(0.002)
Shin Penultimate Pref.		0.007**		0.004
		(0.003)		(0.004)
Shin($T+1$)			0.014**	0.013
			(0.007)	(0.007)
Shin($T+2$)			0.007	0.005
			(0.014)	(0.014)
Shin($T+3$)			−0.013	−0.014
			(0.009)	(0.009)
Shin($T+4$)			0.009	0.008
			(0.005)	(0.005)
Shin($T+5$)			−0.005	−0.007
			(0.005)	(0.004)
Observations	1,863	1,863	1,863	1,863
R-Square	0.309	0.294	0.294	0.286
No. Clusters	47	47	47	47
Prefecture FE	yes	no	yes	no

Note: SE in parentheses, ** significant at 5%, *** significant at 1%.

Table 2
ΔLn(GDP/Capita) By Prefecture (1955–95)

	(1)	(2)	(3)	(4)
ΔLn(Private *K*/Capita)	1.070***	1.057***	1.102***	1.076***
	(0.035)	(0.035)	(0.035)	(0.035)
ΔLn(Public *K*/Capita)	−0.017	−0.019	−0.027	−0.022
	(0.022)	(0.022)	(0.022)	(0.022)
Shinkansen	−0.014***	−0.010***		
	(0.005)	(0.002)		
Seaport	−0.037***	−0.006***	0.041***	0.007***
	(0.006)	(0.004)	(0.002)	(0.003)
Shin Terminus Pref.		0.002		0.001
		(0.002)		(0.002)
Shin Penultimate Pref.		0.004		0.003
		(0.003)		(0.004)
Shin($T+1$)			0.005	0.004
			(0.014)	(0.014)
Shin($T+2$)			−0.019**	−0.020**
			(0.009)	(0.009)
Shin($T+3$)			0.008	0.007
			(0.005)	(0.005)
Shin($T+4$)			−0.015***	−0.016***
			(0.005)	(0.004)
Shin($T+5$)			−0.014	−0.015
			(0.011)	(0.011)
Observations	1,863	1,863	1,863	1,863
R-Square	0.437	0.427	0.435	0.425
No. Clusters	47	47	47	47
Prefecture FE	yes	no	yes	no

Note: SE in parentheses, ** significant at 5%, *** significant at 1%.

The negative coefficient on the Shinkansen fixed effect is in the opposite direction of that expected for productivity improving infrastructure. One explanation is that new Shinkansen lines were introduced between mature cities whose growth rates were already beginning to slow more rapidly than the nation as a whole. A second is that the choice of route was influenced by the recent economic performance of the region. That is, prefectures with slowing growth were favoured as an economic development strategy. The third explanation is one of a sorting of the population through the movement of lower income households to the periphery of cities, thereby changing the economic characteristics of the prefectures in the sense of Combes and Lafourcade (2005) and Baum-Snow (2007).

The first Shinkansen line in the data is the Tokaido line. It was introduced as a replacement for a capacity-constrained line between Osaka and Tokyo, the two largest and most developed cities in Japan. We ran regressions (1) and (2) from both Tables 1 and 2 without the Tokaido line. The coefficients from regressions in Table 1 with the Tokaido line are −0.024 and −0.013. Without the Tokaido line they are −0.020 and −0.017, respectively. For the regressions in Table 2, the coefficients are −0.014 and −0.010. Without the Tokaido line they are −0.011 and −0.012. All coefficients are significant using a

Table 3
Probit Regression on Probability Prefecture has 1982 Opening of Shinkansen Line
Dependent Variable (0,1), with 1 indicating 1982 Shinkansen Line Opened

	Coefficient	*Standard Error*	*Z-Statistic*
GDP Growth Rate Differential	−7.8261	8.469	−0.508
% Rural	−0.4344	0.855	−0.924
S.E. of Regression	0.514		
Akaike Information Criterion	1.538		
Schwartz Criterion	1.635		
Hannan-Quinn Criterion	1.543		
No. Observations	16		

1 per cent critical probability. Consequently, the negative coefficients are not statistically related to the Shinkansen connecting mature cities with slowing growth rates.

To gain insight on the second possible explanation for the negative coefficients, we assembled a data set on the 1982 vintage Shinkansen lines: the Joetsu and Tohuku lines. These two were introduced at the same time. We took as alternative candidates the lines introduced later, and the prefectures adjacent to the Joetsu and Tohuku lines that could have been the location for alternative routing. From the discussion of the placement of previous lines, it is clear that political forces can influence line placement. A Probit model was estimated using the change in the growth of prefecture GDP growth rates in the five years preceding the opening of the line (Table 3). In addition, a variable measuring the extent to which the prefecture was rural was included to sterilise for intermediate predominately rural prefectures, which might have been included on the line as a way of routing to the desired prefecture. That either of these criteria predicts the choice of prefecture for the placement of the line is strongly rejected in the regression.

The third explanation for the result of an increase in population and decrease in GDP growth rates stems from the lower productivity of those households moving into the outlying prefecture.[8] Our housing choice theory implies that lower productivity workers ought to respond to shorter commuting times and lower housing prices made available by the presence of HSR. This is due to both an income effect and the fact that many cultural amenities found in the city core are luxury goods. Similarly, higher-income workers may now find it more attractive to live in the urban core, taking their higher consumption demand with them (Rietveld *et al*., 2001). Although decreasing returns may also explain the result, this has been controlled for with the inclusion of non-Shinkansen prefectures in the regressions.

The regressions on GDP/capita are similar (Table 2). Private investment increases GDP/capita growth rates as expected, but the presence of the Shinkansen and a major port reduces it. Typically, port neighbourhoods are not the most desirable. Residential

[8]This may also have been due in part to the development of lower productivity leisure and hospitality sectors as in Bazin *et al.* (2013), although the results here, particularly as they are robust to changes in income growth, do not indicate that this is the dominant economic force.

neighbourhoods nearby will be populated by lower-skilled, lower-income individuals. The Shinkansen extending the residential reach of cities to their exurbs is having a similar impact.

While the data do not support a growth rate impact of high-speed rail, it is possible that the introduction of high-speed rail provides a one-time boost to the level of GDP and GDP/capita or both, while leaving the growth rates from the new base unchanged. The next set of regressions (Table 4) asks of the data whether or not the level of prefecture GDP is affected by the presence of a Shinkansen line. As with the first set of regressions, the data are from 1955 to 1995 and include measures of prefecture capital stock.

When controlling for the other factors in the aggregate production function, it is found that the Shinkansen had no significant impact on the level of prefecture GDP. All three variables were intended to measure permanent impacts; the presence of a Shinkansen, the prefecture being the terminus of the Shinkansen line, and the prefecture being the first prefecture before the terminus prefecture on the Shinkansen line were not significant. The rationale for the latter two, the terminus and adjacent to terminus prefecture, was to

Table 4
Ln(GDP) By Prefecture (1955–95)

	(1)	(2)	(3)	(4)
Ln(Population)	0.235**	0.454***	0.219**	0.453***
	(0.105)	(0.030)	(0.104)	(0.035)
Ln(Private *K*)	0.994***	0.804***	0.986***	0.807***
	(0.048)	(0.037)	(0.048)	(0.036)
Ln(Public *K*)	−0.366***	−0.197***	−0.363***	−0.198***
	(0.052)	(0.037)	(0.053)	(0.037)
Shinkansen	−0.034	−0.019		
	(0.030)	(0.026)		
Seaport	0.117	0.021	0.108	0.018
	(0.067)	(0.027)	(0.075)	(0.026)
Shin Terminus Pref.		0.014		0.013
		(0.040)		(0.041)
Shin Penultimate Pref.		−0.034		−0.035
		(0.034)		(0.035)
Shin($T+1$)			0.065***	0.082***
			(0.017)	(0.018)
Shin($T+2$)			0.079***	0.095***
			(0.017)	(0.019)
Shin($T+3$)			0.056**	0.076***
			(0.024)	(0.023)
Shin($T+4$)			0.072**	0.093***
			(0.027)	(0.031)
Shin($T+5$)			0.054**	0.073**
			(0.026)	(0.028)
Observations	1,910	1,910	1,910	1,910
R-Square	0.968	0.978	0.969	0.979
No. Clusters	47	47	47	47
Prefecture FE	yes	no	yes	no

Note: SE in parentheses, ** significant at 5%, *** significant at 1%.

test for robustness. The lack of significance of each confirms that heterogeneity of prefectures did not bias the results.

Although no significant positive GDP differences in prefectures with a Shinkansen line were found, the dispersion of populations due to the Shinkansen lowering commuting costs may be related to the fact that the capital stock data restricted the analysis to the rapid-growth period in Japan. To analyse this aspect of HSR, we segmented the differential growth experiences in Japan. We use 1997/8 as the break between growth episodes. After 1997, the Japanese economy cooled considerably, but the expansion of the Shinkansen system to additional prefectures continued. These regressions benefit from additional years of data beyond that for which capital stock data was available.

Table 5 presents regressions for the rapid growth period with GDP/capita as the dependent variable. The coefficient on population density is significant and negative. That is, when density increased, as occurred along the Shinkansen line in outlying prefectures, GDP/capita declined. Again, this likely occurred because lower productivity individuals moved further out, increasing density and decreasing per-capita GDP for the prefectures they moved to, and a smaller cohort of high productivity individuals stayed in or moved into the more amenity-rich city, thereby decreasing density and increasing GDP/capita in

Table 5
ΔLn(GDP/Capita) By Prefecture (1955–97)

	(1)	*(2)*	*(3)*	*(4)*
Population Density	-0.166^{***}	0.000	-0.271^{***}	-0.029^{***}
	(0.000)	(0.000)	(0.000)	(0.000)
ΔLn((GDP/Capita)($t-1$))	0.328^{***}	0.358^{***}	0.352^{***}	0.377^{***}
	(0.026)	(0.022)	(0.027)	(0.023)
Shinkansen	-0.24^{***}	-0.014^{***}		
	(0.004)	(0.002)		
Seaport	-0.031^{***}	-0.007^{**}	-0.039^{***}	-0.009^{***}
	(0.005)	(0.003)	(0.002)	(0.002)
Shin Terminus Pref.		0.003		0.002
		(0.002)		(0.001)
Shin Penultimate Pref.		0.003		0.000
		(0.002)		(0.001)
Shin($T+1$)			0.015	0.015
			(0.018)	(0.017)
Shin($T+2$)			−0.007	−0.007
			(0.012)	(0.012)
Shin($T+3$)			0.031^{***}	0.031^{***}
			(0.007)	(0.007)
Shin($T+4$)			-0.025^{**}	-0.025^{**}
			(0.011)	(0.010)
Shin($T+5$)			0.007	0.006
			(0.006)	(0.006)
Observations	1,974	1,974	1,974	1,974
R-Square	0.163	0.154	0.156	0.151
No. Clusters	47	47	47	47
Prefecture FE	yes	no	yes	no

Note: SE in parentheses, ** significant at 5%, *** significant at 1%.

Table 6
ΔLn(GDP/Capita) By Prefecture (1998–2010)

	(1)	(2)	(3)	(4)
Population Density	−0.891***	0.00	−0.890***	0.00
	(0.000)	(0.000)	(0.000)	(0.000)
ΔLn((GDP/Capita)($t-1$))	−0.115***	−0.097***	−0.113***	−0.093***
	(0.026)	(0.026)	(0.026)	(0.026)
Shinkansen	−0.007***	−0.004**		
	(0.001)	(0.002)		
Seaport	0.00		−0.001	
	(0.006)		(0.006)	
Shin Terminus Pref.		0.004		0.002
		(0.002)		(0.003)
Shin Penultimate Pref.		0.001		−0.001
		(0.002)		(0.002)
Shin($T+1$)			−0.004	0
			(0.008)	(0.007)
Shin($T+2$)			0.024	0.028
			(0.021)	(0.019)
Shin($T+3$)			−0.021	−0.018
			(0.033)	(0.031)
Shin($T+4$)			−0.025***	−0.021***
			(0.006)	(0.004)
Shin($T+5$)			0.004	0.008
			(0.021)	(0.022)
Observations	561	561	561	561
R-Square	0.016	0.011	0.025	0.018
No. Clusters	47	47	47	47
Prefecture FE	yes	no	yes	no

Note: SE in parentheses, ** significant at 5%, *** significant at 1%.

the city core. This result, combined with the negative and statistically significant coefficient for the Shinkansen, is further evidence that the Shinkansen was creating more housing for lower-income people in the exurb prefectures relative to those that did not have a Shinkansen (hypothesis H2).

Table 6 presents the same regressions for the slow growth episode. The results are similar to the rapid growth period. The coefficient on the Shinkansen fixed effect remains negative and statistically significant. The coefficient on population density is also negative and significant, and the magnitude of the coefficient is greater than in the fast growth period. That result likely relates to weaker economic prospects. Wage growth is diminished, and the opportunity cost of time is lower. Thus, living in the denser, costlier city becomes relatively less attractive, and commuting by HSR to a distant suburb becomes relatively more attractive.

In each of the above regressions, fixed effects for each of the first five years after the introduction of HSR were added. Although some of the coefficients were significant and positive, the results were not robust to specification. Nevertheless, the regressions bring out the expected positive impact of construction while it is taking place, and they demonstrate it to be a temporary phenomenon. This impact is from the building of infrastructure, and of housing for those who are choosing to live further from their employment due to the reduced cost of commuting. Once this capital investment is in place, there is no longer a statistically significant change to the level of prefecture income due to the presence of the Shinkansen.

This is not to say that the Shinkansen had no effect. It clearly altered the spatial distribution of population and economic activity. In some HSR station towns, the Shinkansen provided localised economic stimulus. However, viewed a little more widely, this was just rearranging patterns of production and consumption, and not boosting overall economic activity in any permanent way.

Moreover, the Shinkansen, particularly on the Tokaido line but also elsewhere in Japan, connected large vibrant urban economies. It is possible that this connectivity affected business costs related to intra-urban business, and that productivity improvement was spread over Shinkansen present and Shinkansen absent prefectures. However, since our panel includes all prefectures in Japan, including those not in proximity to a Shinkansen present prefecture, these second-order conditions, if they exist, are likely not large.

5.3 Land prices

Additional evidence on housing affordability and HSR comes from land prices. When more land is added to the available residential stock, other things being equal, the price of land

Table 7

Ln(Land Price) By Prefecture (1983–2010)

	(1)	(2)	(3)	(4)
Ln(Population)	−0.798	0.624***	−1.131***	0.616***
	(0.410)	(0.624)	(0.490)	(0.126)
Shinkansen	−0.352***	0.023		
	(0.041)	(0.128)		
Seaport	0.029		0.046	
	(0.188)		(0.212)	
Shin Terminus Pref.		−0.070		−0.014
		(0.208)		(0.216)
Shin Penultimate Pref.		0.004		0.053
		(0.168)		(0.179)
Shin($T+1$)			−0.331***	−0.480***
			(0.100)	(0.100)
Shin($T+2$)			−0.335***	−0.485***
			(0.091)	(0.097)
Shin($T+3$)			−0.276***	−0.461***
			(0.062)	(0.099)
Shin($T+4$)			−0.267***	−0.452***
			(0.052)	(0.103)
Shin($T+5$)			−0.218***	−0.403***
			(0.049)	(0.110)
Observations	1,315	1,315	1,315	1,315
R-Square	0.018	0.383	0.022	0.398
No. Clusters	47	47	47	47
Prefecture FE	yes	no	yes	no

Note: SE in parentheses, ** significant at 5%, *** significant at 1%.

will fall (hypothesis H2). If overall metropolitan economic activity is not affected by the presence of the Shinkansen, and prices for land decline, then we conclude that high-speed rail was a partial solution to housing affordability as it evidently increased the reasonably usable residential land.

We find that Shinkansen connections were negatively associated with average land prices in Japanese prefectures. We regressed the log of land price on the Shinkansen variable. The results are presented in Table 7. For the regressions in which the Shinkansen variables were significant, there was a strong negative impact lasting up to five years after the introduction of the rail line. When controlled for the prefecture being the last or second to last prefecture on the line, the coefficients are not significant. In those regressions the overall impact on land prices is zero, the exurb land price is also unaffected, but the coefficient on the city centre land prices at the terminus of the Shinkansen line is negative and not significant.

When fixed effects for each of the first five years of the line are included, significant negative coefficients are found. While the results in Table 7 indicate a lack of robustness to model specification, in each case they support hypothesis H2, that HSR increased housing affordability, or at a minimum mitigated the trend towards less affordable housing. Regressions using changes in land prices rather than log-levels show similar results (Table 8), although the coefficient for growth rate on the terminus prefecture changes

Table 8
ΔLn(Land Price) By Prefecture (1984–2010)

	(1)	(2)	(3)	(4)
ΔLn(Population)	1.095***	1.109***	1.1026***	1.0784***
	(0.287)	(0.262)	(0.278)	(0.252)
Shinkansen	−0.071***	−0.004		
	(0.014)	(0.005)		
Seaport		0.003		0.001
		(0.003)		(0.002)
Shin Terminus Pref.		0.014**		0.011**
		(0.005)		(0.005)
Shin Penultimate Pref.		0.010		0.007
		(0.006)		(0.005)
Shin($T+1$)			−0.026	−0.027**
			(0.018)	(0.011)
Shin($T+2$)			0.006	0.001
			(0.018)	(0.016)
Shin($T+3$)			0.023	0.019
			(0.033)	(0.031)
Shin($T+4$)			0.019	0.015
			(0.021)	(0.019)
Shin($T+5$)			0.059	0.054
			(0.033)	(0.031)
Observations	1,267	1,267	1,267	1,267
R-Square	0.013	0.010	0.010	0.011
No. Clusters	47	47	47	47
Prefecture FE	yes	no	yes	no

Note: SE in parentheses, ** significant at 5%, *** significant at 1%.

sign. Nevertheless, the estimated increase in the change in land price for those prefectures is quite small.

6.0 Conclusion

That HSR increases the convenience of living in outlying suburbs of crowded and expensive cities is self-evident. What has not been clear before is whether or not HSR may serve as one of the solutions to a lack of affordable housing. Were HSR to induce rapid economic growth along the line, it is possible that housing nearby would be more expensive, rather than cheaper. In this study, we examined the experience in Japan, and we found that over a 55-year period, the Shinkansen did not induce more rapid economic growth in prefectures where it operated, but it did ease land costs and relieve some of the pressure on home prices in major cities.

Decentralisation is consistent with the results we find: the Shinkansen helped Japanese cities to decentralise, which in return reduced property prices in cities from what they otherwise might have been. The limitation of these results stems from the fact that they are at the prefecture level. There is ample evidence that in sections of the city core and along the HSR line, sub-prefecture land prices increased. Identifying these neighbourhoods and obtaining data on them are problematic tasks, but do not diminish the implications of the prefecture-wide empirical results.

Although we focus on Japan in order to study the most extensive system of HSR over the longest period of time, the single country analysis is, of course, limited due to factors specific to Japan. Cross-sectional panel analysis with multiple countries, but more limited time frames, will provide additional evidence, and is the subject of further research.

Our analysis also showed that there may be a temporary boost to GDP growth rates as the infrastructure and housing associated with a newly built HSR along the rail line are constructed. However, the gains are not long lasting.

Although more micro-studies are needed to confirm the generality of our results, our findings point to a promising new avenue for affordable housing policy. Planners crafting policy ought to evaluate the optimal allocation of scarce housing resources by weighing the costs and benefits of building transportation infrastructure, which adds residential land against the costs and benefits of building additional residential units on existing city land closer to the city centre.

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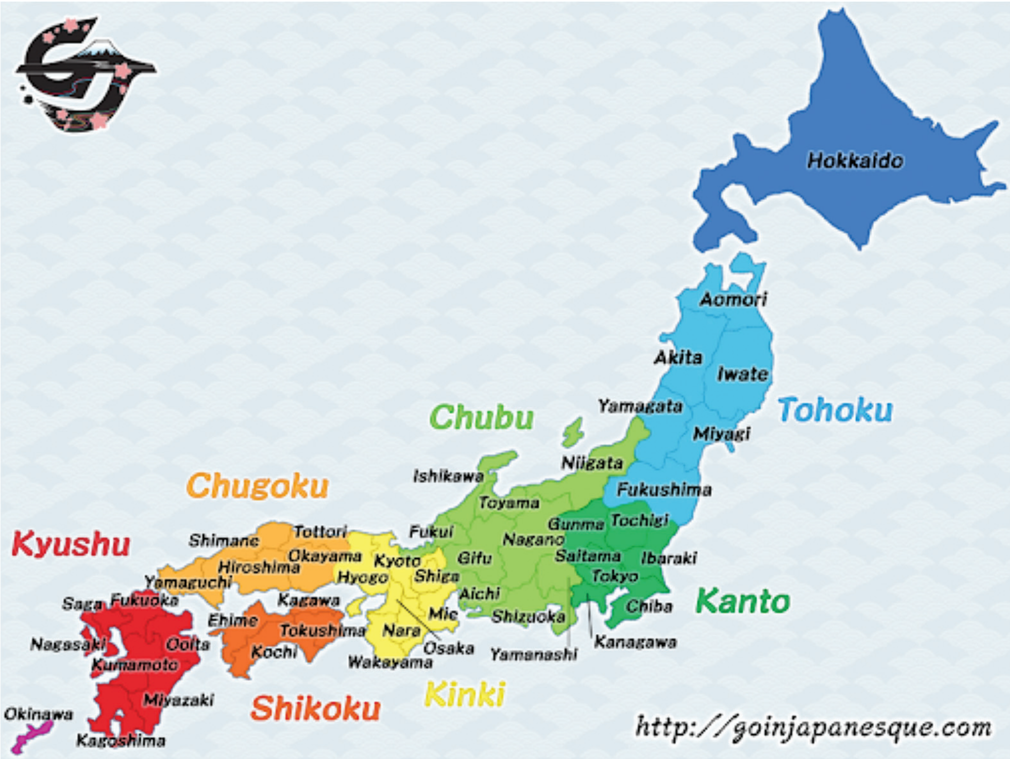
Appendix A: Data Description

Summary Statistics

Variable name	*Definition*	*Obs*	*Mean*	*St. dev.*
Shinkansen	Dummy variable = 1, if for the year Shinkansen was present in the prefecture	2,687	0.278005	0.448099
Shin($T+1$)	Dummy variable = 1, if Shinkansen started in that prefecture one year ago	2,688	0.008557	0.092122
Shin($T+2$)	Dummy variable = 1, if Shinkansen started in that prefecture two years ago	2,688	0.008557	0.092122
Shin($T+3$)	Dummy variable = 1, if Shinkansen started in that prefecture three years ago	2,688	0.008557	0.092122
Shin($T+4$)	Dummy variable = 1, if Shinkansen started in that prefecture four years ago	2,688	0.008557	0.092122
Shin($T+5$)	Dummy variable = 1, if Shinkansen started in that prefecture five years ago	2,688	0.008557	0.092122
GDP	Real Gross Domestic Product	2,688	11,600,000	49,400,000
GDP Growth	GDP Growth at time t is defined as $\ln(\text{GDP}_t) - \ln(\text{GDP}_{t-1})$	2,585	0.042034	0.057194
GDP/Capita	GDP/Population	2,631	2.438759	1.18996
GDP Per Capita Growth	GDP Per Capita Growth at time t is defined as $\ln(\text{GDP/Capita}_t) - \ln(\text{GDP/Capita}_{t-1})$	2,583	0.038439	0.060862
Private K	Private Capital Stock	1,927	6,584,770	11,300,000
Public K	Public Capital Stock	1,927	4,454,266	6,222,292
Population Growth	Population Growth at time t is defined as $\ln(\text{Population}_t) - \ln(\text{Population}_{t-1})$	2,583	0.003952	0.022708
Population Density	Population/Area	2,631	0.564326	0.992123
Airport	Dummy variable = 1, if a class 2 or class 1 airport is in the prefecture for the year	2,688	0.386905	1.397752
Seaport	Dummy variable = 1, if a seaport is in the prefecture for the year	2,688	0.052827	0.22373
Shin. Terminus	Dummy variable = 1, if the prefecture is the last terminal on a Shinkansen line	2,632	0.148936	0.356093
Shin. Penultimate	Dummy variable = 1, if the prefecture is the second last terminal on a Shinkansen line	2,632	0.170213	0.375891
Land Price	The actual price of real estate transaction in Japan, announced by the Ministry of Land, Infrastructure and Transport	1,316	133,766.4	239,541
Change in Land Price	Change in land price at time t is defined as $\ln(\text{Land Price}_t) - \ln(\text{Land Price}_{t-1})$	1,269	−0.000961	0.142352

Appendix B: Maps of Prefectures and Shinkansen Lines




Shinkansen Lines (Current as of March 2016)
In operation
Planned or under construction
Hokkaidō Shinkansen
(Extension to Sapporo is scheduled for 2030.)
Sapporo
Shin-Hakodate-Hokuto
Akita Shinkansen
Shin-Aomori
Tōhoku Shinkansen
Yamagata Shinkansen
Morioka
Akita
Hokuriku Shinkansen
Shinjō
(Extension from Kanazawa to Tsuruga is scheduled for 2022.)
Yamagata
Sendai
Fukushima
Niigata
Kyūshū Shinkansen (Nagasaki route)
Jōetsu Shinkansen
Kanazawa
(Extension to Nagasaki scheduled for 2022.)
Nagano
Takasaki
Ōmiya
Tsuruga
San'yō Shinkansen
Tokyo
Shin-Yokohama
Kyoto
Hiroshima
Hakata
Shin-Osaka
Nagoya
Linear Chūō Shinkansen
Shin-Tosu
Tōkaidō Shinkansen
(Service between Shinagawa and Nagoya is scheduled to begin in 2027, with service to Osaka scheduled for 2045.)
Nagasaki
*The route between Nagoya and Osaka has yet to be decided.
Kyūshū Shinkansen (Kagoshima route)
Kagoshima Chūō
nippon.com