Trade Integration, Market Size, And Industrialization: Evidence From China's National Trunk Highway System*

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Abstract

This paper presents evidence in favor of the hypothesis that trade integration between large and small markets can reinforce the concentration of economic activity. Krugman's (1980) home market effect provided a microfoundation for the proposition that market size is a determinant of industrialization. The same channel also has important, yet so far untested implications for the consequences of falling trade costs between asymmetric markets. I exploit China's National Trunk Highway System as a large scale natural experiment to test for the home market channel of trade integration. The network was designed to connect provincial capitals and cities with an urban population above 500,000. As a side effect, a large number of small peripheral counties were connected to large metropolitan city regions. To guide estimation, I derive qualitative and quantitative predictions from a tractable general equilibrium trade model. To test these predictions, I construct least cost path spanning tree networks as instruments for route placements on the way between targeted city nodes. The results suggest that network connections had negative growth effects among peripheral counties due to reduced industrial output growth. Counterfactual estimations of the calibrated structural model suggest that the home market channel can both qualitatively and quantitatively account for the observed effects.

Keywords: Market integration; transport infrastructure; home market effect
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1 Introduction

A large share of world trade takes place between regions within countries.[1] In this context, transport infrastructure investments have been a prominent policy tool that directly affects the degree of within-country trade integration.[2] These policies frequently combine national efficiency with regional equity objectives under the presumption that integration promotes both growth as well as the spreading of economic activity to peripheral regions.[3]

Trade theory has suggested otherwise. In the presence of increasing returns to scale in production, the home market effect in Krugman (1980) and Helpman and Krugman (1985) provided a microfoundation for the idea that market size is a determinant of industrialization. The same microeconomic channel also suggests that falling trade costs between *ex ante* asymmetric regions can reinforce the concentration of economic activity. Despite the fact that transport networks almost inevitably connect both metropolitan and peripheral regions, our existing empirical knowledge about the role of market size in trade integration is very limited.

This paper exploits China's National Trunk Highway System (NTHS) as a large scale natural experiment to contribute to our understanding of this question. The first contribution is related to a growing body of empirical evaluations of transport infrastructure.[4] It has been an implicit assumption of this literature that relative market size has no implications for the consequences of falling trade costs. A common basis for this assumption is the neoclassical tradition of constant returns to scale in production. This paper relaxes this assumption and exploits the NTHS as a source of plausibly exogenous variation in trade cost shocks across a large number of *ex ante* asymmetric regions to learn about the role of market size in trade integration.

A second contribution is to present a novel empirical test of one of the central microeconomic channels of new trade theory. Existing empirical literature on the home market effect has mainly followed the original comparative static in Krugman (1980) and Helpman

[1] This follows from the gravity literature in international trade. For evidence using microdata on US plant transactions see Hilberry and Hummels (2008).

[2] Transport infrastructure has been the second most important spending category in World Bank lending over 2001-06, of which 73% were spent on highways and roads (www.worldbank.org).

[3] From the World Bank's Transport Business Strategy 2008-2012 (2008, pp. 03): "*One of the best ways to promote rural development is to ensure good accessibility to growing and competitive urban markets.*" For a discussion of the combination of efficiency with regional equity objectives in the context of European Structural Fund spending on transport see Puga (2002).

[4] See discussion of related literature further below in this section for references.

and Krugman (1985) in terms of a testable cross-sectional relationship between consumption and production shares across countries. This paper, on the other hand, exploits a large scale infrastructure policy to test for the home market channel in the context of falling trade costs.

The findings of the paper present evidence in favor of the home market channel of integration. The main results can be summarized as follows. NTHS network connections had a significant negative effect on GDP growth among peripheral counties on the way between the targeted metropolitan network nodes relative to non-connected peripheral counties due to reduced industrial output growth. These effects vary significantly across pre-existing county characteristics as predicted by theory. Counterfactual estimations of the calibrated structural model suggest that the home market channel can both qualitatively and quantitatively account for the observed effects. Finally, counterfactual policy simulations suggest significant aggregate welfare gains from trade, and provide the insight that the observed increase in concentration of nominal production does not necessarily imply parallel welfare distributional consequences due to significant price index reductions among connected peripheral counties.

To guide estimation, I adapt the canonical model in Helpman and Krugman (1985) to an empirical setting with multiple and *ex ante* asymmetric regions.[5] In addition to the tractability and closed form solutions that this choice facilitates, it assures that the predictions and their empirical evaluation are based on the identical set of economic forces that underlie the original microfoundation of the home market effect.

In a first step, I derive a series of qualitative predictions on both average connection effects as well as their heterogeneity with respect to pre-existing county characteristics from a tractable three region policy scenario. In the second step, I derive quantitative predictions in the full multi-region setting based on simulations of the calibrated structural model subject to observed inter-county trade cost changes from Chinese transport network data.

To empirically test these predictions one requires exogenous variation in trade cost changes across a sufficient number of *ex ante* asymmetric regions. In this context, China's NTHS provides a wide range of pre-existing regional size asymmetries in combination with the explicit targeting of a subset of metropolitan network nodes. Its stated objectives were to

[5] Krugman (1980) and Helpman and Krugman (1985) are based on identical microfoundations of the home market effect but impose alternative conditions to pin down equilibrium outcomes. The former imposes regional trade balance conditions, whereas the latter introduces a freely tradeable numeraire sector. The choice of the Helpman-Krugman model is due to its maintained tractability in a multi-asymmetric region setting. See also Behrens *et al.* (2009) for a discussion of this choice in a multi-region setting.

connect provincial capitals, cities with an urban registered population above 500,000, and border crossings on a single expressway network (World Bank, 2007b, see Figure 1). While the targeted metropolitan city centers represented less than 1.5% of China's land area and 14% of its population, they accounted for 50% of China's non-agricultural production before the bulk of the network was built in 1997. The average pre-existing market size difference between non-targeted peripheral counties and targeted metropolitan city centers was 1:24 in terms of county GDP.

Despite the stated objectives, the assumption of random route placements on the way between targeted city nodes would be strong. Both the NTHS planning process and descriptive statistics suggest that planners targeted politically important and economically prosperous counties on the way between targeted destinations. To address these concerns I propose an instrumental variable strategy based on hypothetical least cost path spanning tree networks. These correspond to the question which routes planners would have been likely to build if the sole policy objective had been to connect all targeted destinations subject to construction cost minimization. I use remote sensing data on land cover and elevation in combination with Dijkstra's (1959) optimal route algorithm to compute least costly construction paths between targeted destinations. I then feed these bilateral cost parameters into Kruskal's (1956) minimum spanning tree algorithm to identify the subset of routes that connect all targeted nodes to minimize network construction costs. I also construct a more extensive, but less precise straight line spanning tree network that is subject to a different trade-off between route precision and the number of captured bilateral connections.[6]

The baseline identifying assumption is that county location along an all-China least cost spanning tree network affects changes of county level economic outcomes only through NTHS highway connections, conditional on province fixed effects, distance to the nearest targeted node, and controls for pre-existing political and economic characteristics. To assess the validity of the exclusion restriction I report how baseline IV point estimates are affected by the inclusion of county controls, and test the model's predictions on the heterogeneity of the connection effects. In addition, the relatively recent nature of the NTHS also allows me to test for network connection effects on identical county samples both before and after the

[6]The second network is related to Banerjee *et al.* (2009) who propose straight line connections between Treaty Ports and historical cities as instruments for railway lines. The combination of least cost path routes, such as straight lines, with a spanning tree algorithm allows me to instrument for the choice of bilateral connections in addition to route placements on any given connection.

network was built as a placebo falsification test.

In conclusion, the paper provides two novel insights. First, the paper presents evidence in favor of the hypothesis that market integration can reinforce the concentration of economic activity. Second, the paper presents a novel empirical test of the home market effect using a very different setting and source of variation compared to existing literature discussed below. These findings are in support of theoretically motivated policy discussions in the trade literature (Fujita *et al.*, 1999; Baldwin *et al.,* 2003), and serve to emphasize the importance of potentially unintended general equilibrium consequences when evaluating and planning large scale transport infrastructure policies.

This research is related to existing empirical literature on the home market effect in international trade (Davis and Weinstein, 1996; 1999; 2003; Head and Ries, 2001; Hanson and Xiang, 2004; Brulhart and Trionfetti, 2009). This literature has mainly followed the original comparative static result of the home market effect in Krugman (1980) and Helpman and Krugman (1985), that an increase in relative market size leads to an increase in the share of industrial production[7], and adapted it to a multi-sector industrial setting in order to exploit variation in markets sizes and production across countries and industries.[8] Instead of relying on cross-sectional variation in consumption and production shares, this paper tests for the home market channel in the context of falling trade costs between *ex ante* asymmetric regions.

The paper is also related to a growing empirical literature on the evaluation of transport infrastructure. Recent contributions have studied the economic effects on suburbanization (Baum-Snow, 2007), skill premia in local labor markets (Michaels, 2008), long term GDP effects (Banerjee *et al.*, 2009), gains from trade (Donaldson, 2010), urban form (Baum-Snow *et al.*, 2012), and city growth (Duranton and Turner, 2012).[9] This paper's contribution is to

[7]There is debate about the robustness of the home market effect. Davis (1998) finds that it disappears when all sectors incur transport costs. Krugman and Venables (1999) show that the home market effect exists as long as some homogenous goods have low transport costs or some differentiated goods have zero fixed costs.

[8]A notable exception is Head and Ries (2001) who also follow the original prediction, but in addition report results on how changes in US-Canada trade barriers affect production shares depending on pre-existing relative market sizes across industries. They do not find evidence in support of the home market channel of integration. Rather than using cross-sector variation within manufacturing between two integrating countries, the present paper exploits variation in trade cost shocks across a large number of asymmetric regions within a country. Also note that not all existing studies rely on a cross-country setting. Davis and Weinstein (1999) use variation in consumption and production shares across Japanese regions.

[9]In a related paper Banerjee *et al.* (2009) use straight line connections between Treaty Ports and historical cities in China to study long term average effects of railway connections in the late 19th and early 20th century on contemporary economic outcomes. This paper's focus is on the role of market size in contemporary trade integration in an emerging market environment subject to road network additions.

study a large scale infrastructure policy to test increasing returns to scale trade theory and learn about the role of market size in trade integration.

The remainder of the paper is structured as follows. Section 2 presents the model and derives a set of qualitative predictions to guide estimation. Section 3 describes the policy background and data. Section 4 presents the empirical strategy. Section 5 reports estimation results. Section 6 presents the quantitative analysis and counterfactual estimations. Section 7 concludes.

2 The Model

The model is based on Helpman and Krugman (1985) and adapted to a setting with multiple and *ex ante* asymmetric regions. In addition, I introduce capital as an input to industrial production and allow this factor to be mobile across regions as in Martin and Rogers (1995). As discussed in more detail below, this serves to adapt the original cross-country model without factor mobility to a within country setting with partial factor mobility without altering the original set of microeconomic forces at play.

The economy is populated by a continuum of agents who are distributed over R regions. There are two sectors of production, labelled agriculture (A) and industry (M), and two factors of production labelled labor (L) and capital (K). The former is assumed to be immobile across regions, while the latter is mobile. Mobile stocks of capital are owned by workers, and returns to capital are repatriated across regions.

2.1 Preferences

The representative consumer in each region has two-tier preferences, where the upper tier is a Cobb-Douglas nest of consumption of agriculture (which will be the numeraire good) and a composite of industrial varieties. Industrial goods enter as a constant elasticity of substitution (CES) sub-utility function defined over a continuum of industrial varieties $i(i = 1, 2, ...N)$. Consumer utility in region $j(j = 1, 2, ...R)$ is given by:

$$U_j = C_{Mj}^{\mu} C_{Aj}^{1-\mu} \quad C_{Mj} = \left(\int_{i=0}^{N} c_{ij}^{1-1/\sigma} di \right)^{\frac{1}{(1-1/\sigma)}} \qquad 0<\mu<1<\sigma \tag{1}$$

C_{Mj} and C_{Aj} are consumption of industry and agriculture in region j respectively, c_{ij} is consumption of manufacturing variety i in region j, μ is the expenditure share on industry, and σ is the elasticity of substitution between varieties. Standard utility maximization yields a constant division of expenditure between sectors and CES demand for an industrial variety i in region j:

$$c_{ij} = \frac{p_{ij}^{-\sigma}}{\int_{i=0}^{N} p_{ij}^{1-\sigma} di} \mu Y_j \tag{2}$$

Y_j is total regional factor income of labor (L_j) and capital (K_j), with wage rate w_j and capital return π_j:

$$Y_j = w_j L_j + \pi_j K_j \tag{3}$$

2.2 Technology

The numeraire agricultural sector requires a_A units of labor to make one unit of A. It is subject to perfect competition, constant returns to scale and faces no trade costs. Marginal cost pricing implies that $p_{Aj} = a_A w_j$ and costless trade equalizes prices and wages across regions so that $p_{Aj} = p_A$ and $w_j = w$ as long as some positive fraction of A is produced in every region.[10]

The industrial sector M is subject to increasing returns, Dixit-Stiglitz monopolistic competition and iceberg trade costs. Each firm of a continuum of industrial producers requires one fixed cost unit of capital K, and a_M units of L to produce a unit of M. This implies a cost function $\pi + w a_M x$, where x is firm level output. It is costless to ship industrial goods within a region, but $\tau_{jk} - 1$ units of the good are used up in transportation between two regions j and k. It is assumed that $\tau_{jk} = \tau_{kj}$. It proves convenient to define $\phi_{jk} = \tau_{jk}^{1-\sigma}$ as the "freeness" of trade ranging from 0 (prohibitive costs) to 1 (costless trade).

Dixit-Stiglitz monopolistic competition and demand in (2) imply that mill pricing is optimal for industrial firms, so that the price ratio of a variety in an export region k over its local market price in j is τ_{jk}. For a variety i produced in region j but also sold in another region k this is:

[10] The Online Appendix derives the formal condition of incomplete specialization across regions.

$$p_{ij} = \frac{wa_M}{1 - 1/\sigma}, \;\; p_{ik} = \tau_{jk}\frac{wa_M}{1 - 1/\sigma} \tag{4}$$

2.3 Equilibrium

Because the marginal cost of industrial firms depends on the immobile factor whose price is pinned down by costless trade in the numeraire sector, industrial f.o.b. prices are equalized across regions and consumer prices differ only by transport costs. As capital enters as fixed cost component in industrial production, this also implies that capital returns are equal to the operating profit of a typical variety. Under Dixit-Stiglitz competition, this is equal to the value of sales divided by σ. Normalizing the price of agriculture to be the numeraire and choosing units of A such that $p_A = a_A = w = 1$, we can use demand in (2) and mill pricing in (4) to solve for the equilibrium returns to the mobile factor:

$$\pi_j = \left(\sum_k \frac{\phi_{jk} S_{Yk}}{\sum_m \phi_{mk} S_{Nm}} \right) \frac{\mu}{\sigma} \frac{Y}{K} \tag{5}$$

S_Y represents regional shares of total expenditure, and S_N are regional shares of the mass of total industrial varieties. Y and K stand for total expenditure and the total capital endowment across all regions respectively. Given repatriation of capital returns to immobile owners, regional expenditure shares are a deterministic function over regional shares of capital owners and labor endowments, S_K and S_L respectively:

$$S_{Yj} = \left(1 - \frac{\mu}{\sigma}\right) S_{Lj} + \frac{\mu}{\sigma} S_{Kj} \tag{6}$$

Because capital is freely mobile across regions, there are two possible types of equilibria: core-periphery outcomes where S_N can be 0 or 1, and interior location equilibria. Given all regions maintain some positive fraction of industrial activity, capital returns are equalized so that the long run equilibrium location condition is given by $\pi_j = \pi$ for $0 < S_{Nj} < 1$. The profit equation (5) coupled with inter-regional profit equalization yield a system of R equations that can be solved for an $R * 1$ vector of regional industrial production shares as a function of an $R * R$ bilateral trade cost matrix and an $R * 1$ vector of regional expenditure shares that are in turn determined by regional endowments as stated in (6).

2.4 Discussion

Equilibrium profits in (5) are a positive function of access to consumer expenditure, and decreasing in access to competing industrial producers. The interplay between these two channels, where the former enters as agglomeration force and the latter as dispersion force, gives rise to the home market effect in the original two region setting of Helpman and Krugman (1985) as soon as the regional symmetry in expenditure shares is broken.

Considering profits in (5) in the original two region setting, it is readily shown that the direct corollary comparative static result of the home market effect is that falling trade costs between two *ex ante* asymmetric markets lead to an increase of industrial concentration in the larger market.[11] The intuition behind this result is that falling trade costs attenuate both the agglomeration and the dispersion force, but at differential rates. On one hand, lower trade costs decrease the relative disadvantage of higher product market competition in the larger market because the relative increase in competition is stronger for the smaller region.

On the other hand, lower trade costs also decrease the market access advantage of the larger region because the relative increase in market access is stronger for the smaller region. The microfoundation of the home market channel of trade integration is that the decrease in regional differences of market competition outweighs the decrease in market access differentials. Falling trade costs attenuate the dispersion force at a faster rate than the agglomeration force.

The introduction of capital mobility to the Helpman-Krugman model extends this effect to total production rather than just industrial production, without altering the original microeconomic channel at work. Because capital returns are repatriated to immobile owners, capital mobility does not introduce additional self-reinforcing agglomeration forces as in the new economic geography literature (Fujita *et al.*, 1999). It does, however, allow for the possibility that integration leads to reinforced concentration of aggregate economic activity, as

[11] Denote a larger "core" region by superscript C and a smaller peripheral region by superscript P. The profit equation for the periphery becomes: $\pi^P = \left(\frac{S_Y^P}{S_N^P + \phi(1-S_N^P)} + \phi\frac{1-S_Y^P}{\phi S_N^P + 1 - S_N^P}\right)\frac{\mu}{\sigma}\frac{Y}{K}$. Given an isomorphic expression for the core region and equalization of capital returns, we can solve for: $S_N^P = \frac{1}{2} + \left(\frac{1+\phi}{1-\phi}\right)\left(S_Y^P - \frac{1}{2}\right)$. The derivative over trade freeness is $\frac{\partial S_N^P}{\partial \phi} = \frac{\phi+1}{(\phi-1)^2}\left(S_Y^P - \frac{1}{2}\right) - \frac{\phi-1}{(\phi-1)^2}\left(S_Y^P - \frac{1}{2}\right)$. This is positive for regions with $S_Y > \frac{1}{2}$, zero for symmetric regions, and negative for regions with $S_Y < \frac{1}{2}$.

regional GDP changes in parallel to industrial production when a factor used in the production of industry is mobile. This relationship is less than proportional because the immobile factor of production remains productive within the region.

Finally, capital mobility enters in combination with immobile labor in the model. In addition to the tractability and closed form solutions that this choice facilitates, there are two deeper reasons. First labor mobility would reinforce the centripetal force of integration already present in the model by adding an agglomeration force of "circular causation" that is not present in the original microfoundation of the home market effect. Second, in the Chinese setting there is a compelling empirical case to be made for a channel of integration that does not rely on perfect labor mobility. The household registration or "hukou" system represents a well documented restriction on migration flows (e.g. Au and Henderson, 2006).

2.5 Qualitative predictions from a three-region policy scenario

This subsection derives a series of closed form qualitative predictions from a tractable policy scenario to motivate the empirical analysis. It is evident from (5) that predictions in a full multi-region setting require the parameterization of the $R*R$ matrix of initial bilateral trade costs, their changes, as well as the vector of initial expenditure shares. This approach will be taken in Section 6 to derive quantitative predictions from the calibrated structural model. Proofs of the following propositions are rendered to the Online Appendix.

Empirical estimations will be based on the comparison of changes of economic outcomes among peripheral county regions that were connected to new NTHS routes relative to non-connected peripheral counties. Given that in general equilibrium it would be a strong assumption that non-connected regions are not affected at all by the network, the most basic policy scenario thus requires at least three regions. Consider two initially identical peripheral regions and one larger metropolitan core region, denoted by superscripts $P1$, $P2$ and C respectively, that are identical in terms of tastes, technology, and initial bilateral trade costs. Geometrically, one can think of this scenario as three regions located on the endpoints of an equilateral triangle. The profit equation in the first peripheral region becomes:

$$\pi^{P1} = \left(\frac{S_Y^{P1}}{S_N^{P1} + (1 - S_N^{P1})\phi} + \phi \frac{S_Y^{C}}{S_N^{C} + (1 - S_N^{C})\phi} + \phi \frac{S_Y^{P2}}{S_N^{P2} + (1 - S_N^{P2})\phi} \right) \frac{\mu}{\sigma} \frac{Y}{K} \qquad (7)$$

Profits in the core region are isomorphic, and profits in the second peripheral region are given by $\pi^{P2} = 1 - \pi^{P1} - \pi^{C}$. Initial peripheral symmetry implies that $S_Y^{P1} = S_Y^{P2}$, and ϕ is the identical bilateral trade freeness between all three regions at an initial period. We now introduce asymmetric trade integration in the most convenient way. Let $\alpha\phi$ denote the bilateral trade freeness between peripheral region 1 and the core region after a negative bilateral trade cost shock, while ϕ is the unchanged initial trade freeness between all regions. Initially, $\alpha = 1$, while after the trade cost shock takes effect, α is in the range $1 < \alpha < \frac{1}{\phi}$.[12]

Using peripheral symmetry ($S_Y^{P2} = S_Y^{P1}$), introducing the asymmetric trade cost shock ($\phi^{P1} = \alpha\phi$), and solving for the equilibrium difference of industrial activity between connected and non-connected peripheral regions subject to profit equalization $\pi^{P1} = \pi^{P2} = \pi^{C}$, we get:

$$S_N^{P1} - S_N^{P2} = \left(\left(\frac{1}{2} - \frac{3}{2}S_Y^C\right)\frac{(\alpha-1)\phi}{1-\alpha\phi} + 1\right)\frac{1+\alpha\phi-2\phi^2}{(1-\phi)(1+\alpha\phi-2\phi)} - \frac{3\phi}{1+\alpha\phi-2\phi} - 1 \quad (8)$$

This provides a closed form solution for peripheral differences in industrial activity as a function of relative market sizes, initial levels of trade costs, and the degree of asymmetric trade integration. At the initial $\alpha = 1$ position, perfect symmetry between peripheral regions leads to $S_N^{P1} - S_N^{P2} = 0$. The question is what happens to industrial production in the connected peripheral county relative to the non-connected one after the trade cost shock materializes. The derivative of interest is $\frac{\partial(S_N^{P1} - S_N^{P2})}{\partial\alpha}$. As can be seen from (8), the sign of this derivative in principle depends on the extent of the pre-existing core-periphery gradient summarized in S_Y^C, the level of pre-existing trade integration ϕ, as well as the extent of asymmetric trade integration captured by α.

It is clear from (8) that for any given scenario of core-periphery integration $1 < \alpha < \frac{1}{\phi}$ and initial trade costs ϕ, the difference in industrial production shares between the integrating and the non-integrating periphery becomes more negative as the core-periphery size asymmetry (summarized by S_Y^C) increases. Using this insight, one can solve for the necessary degree of the core-periphery gradient at which $\frac{\partial(S_N^{P1} - S_N^{P2})}{\partial\alpha} < 0$ holds for any combination of initial trade costs and trade cost shock asymmetry. As long as the metropolitan region is at least twice the size of an individual peripheral region, $\frac{\partial(S_N^{P1} - S_N^{P2})}{\partial\alpha} < 0$ holds across any configuration of ϕ and α.[13] The Online Appendix provides proofs of this result and the following propositions.

[12] This is equivalent to modeling a proportional change of the iceberg trade cost (τ) between the integrating peripheral and the core region. Let $\phi^{P1} = (\widetilde{\alpha}\tau)^{1-\sigma}$, where $\frac{1}{\tau} < \widetilde{\alpha} < 1$, then $\alpha = \widetilde{\alpha}^{(1-\sigma)}$.

[13] Existing theoretical literature on preferential trade integration in a setting with increasing returns to

Proposition 1 *Falling trade costs between a sufficiently uneven core-periphery pair of regions lead to a reduction of industrial production in the integrating periphery relative to a non-integrating peripheral control region.*

Descriptive statistics in Table 1 give a clear indication that the model's size asymmetry threshold is exceeded when comparing non-targeted peripheral counties to the targeted metropolitan city regions.[14] Following from the previous discussion, the model makes additional predictions about county level changes to overall GDP and agricultural output. Aggregate GDP moves in parallel to industrial output, but less than proportional because labor formerly used by industry remains productive in the region. Proposition 1 thus holds for aggregate production, but we expect a lower point estimate on the elasticity of peripheral GDP to trade cost reductions compared to industrial activity. The reallocation of labor to the agricultural numeraire sector implies that falling trade costs have the opposite effect on agricultural output growth.

Proposition 2 *The negative effect of integration holds, but to a lesser extent, for total regional production, and is reversed in sign for agricultural production.*

In addition to the predictions on the average effects of integration among peripheral counties formalized in Propositions 1 and 2, the richness of the empirical setting also allows to test how the home market channel should affect peripheral counties differently. From (8), the first cross-derivative prediction is that the home market effect should be more pronounced among peripheral counties whose initial level of trade costs vis-a-vis the core region is lower: $\frac{\partial^2(S_N^{P1}-S_N^{P2})}{\partial\alpha\partial\phi} < 0$. For a given trade cost reduction, the marginal effect on industrial and aggregate production should be more negative at higher initial levels of ϕ.

Proposition 3 *The negative effects of integration on industrial and total production are more pronounced among peripheral regions with initially lower trade costs to the larger core region.*

scale production has found increased industrial output in the trading block relative to the non-integrating region (Puga and Venables, 1997). The focus of the present analysis is on the consequences of preferential integration when regions within the trading block are asymmetric. An important feature is the tractability of the present model which allows me to consider a wide range of regional size asymmetries in the context of China. This is in contrast to simulations of infinitessimal deviations from perfect symmetry used in new economic geography models.

[14]Beyond the three-region case, all predictions will also be confirmed in the simulation results of the calibrated full multi-region model in Section 6.

This interaction effect is related to what the trade literature has referred to as home market magnification (Baldwin *et al.*, 2003). The intuition is that falling trade costs attenuate the peripheral location advantage of less market crowding at a faster rate than the metropolitan market access advantage, so that at lower initial trade costs between core and periphery a given trade cost reduction will require a larger relocation of industrial production to equalize the rate of capital return.[15]

The second cross-derivative prediction is that, holding initial trade freeness constant, the home market effect is stronger among peripheral counties whose size differential vis-a-vis the core is more pronounced: $\frac{\partial^2 (S_N^{P1} - S_N^{P2})}{\partial \alpha \partial S_Y^C} < 0$.

Proposition 4 *The negative effects of integration on industrial and total production are more pronounced among peripheral regions with an initially stronger market size differential to the core region.*

The prediction that the home market channel should operate more strongly among smaller peripheral regions is also intuitive. Falling trade costs weaken the dispersion force at a faster rate than the agglomeration force, so that for a larger core-periphery size gradient, and thus higher initial levels of agglomeration and dispersion forces, a given trade cost reduction requires more industrial concentration in the core to equalize profits. The Online Appendix provides a graphical illustration of Propositions 1-4 for a set of parameter combinations.

3 Background And Data

3.1 China's National Trunk Highway System

In 1992, the Chinese State Council approved the construction of the "7-5" network, consisting of seven horizontal and five vertical axes, under the National Trunk Highway Development Program (Asian Infrastructure Monthly, 1995; World Bank, 2007b) (see Figure 1). The NTHS was constructed at an estimated cost of US$ 120 billion over a 15-year period until the end of 2007, spanning approximately 35,000 km of high speed four-lane highways (Li and Shum, 2001; Asian Development Bank, 2007; World Bank, 2007a).

[15] Notice that this result is not driven by the choice of modelling trade integration in terms of a proportional reduction in τ. All predictions hold when considering absolute changes in τ instead, but the former are more convenient for deriving closed form solutions.

Its stated objectives were to connect all provincial capitals and cities with an urban registered population above 500,000 on a single expressway network, and to construct routes between targeted centers and the border in border provinces as part of the Asian Highway Network. NTHS routes are four-lane high speed limited access toll ways. The speed limit is 120 km/h, and a common minimum speed limit is 70km/h. Road quality, congestion, and driving speed of the modern expressways are in clear contrast to pre-existing national highways (speed limit 100 km/h) and provincial highways (speed limit 80 km/h) that are also subject to road tolls.

The network was originally earmarked for completion by 2020, but was completed ahead of schedule by the end of 2007. Planners at the Chinese Ministry of Communications divide the construction into a "kick-off" phase between 1992-1997, and "rapid development" between 1998-2007 (World Bank, 2007a). The reason behind the acceleration of construction efforts in 1998 is that highway construction became part of the government's stimulus spending after the Asian financial crisis (Asian Development Bank, 2007).

To finance the great majority of NTHS routes, the central government encouraged province and county level governments to raise funds by borrowing against future toll revenues. Roughly 70% was financed from province and county level debt, and 10-15% was contributed by the central government. Private sector participation was also encouraged with up to 5% of financing stemming from domestic and foreign investors (Asian Development Bank, 2007).

Construction was undertaken almost entirely by Chinese state owned enterprises, part of which were assigned directly to particular localities, part of which were participating in contract auctions.[16] Given the progress in the construction of the NTHS ahead of plan, the State Council approved an even more ambitious follow-up blue print for highway construction in 2004. The so called "7-9-18" system has the stated objective to connect all cities with an urban registered population of more than 200,000. It is scheduled to be completed by 2020.

3.2 Data

Geo-referenced administrative boundary data for the year 1999 was obtained from the ACASIAN Data Center at Griffith University in Brisbane, Australia. These data provide a county-level geographical information system (GIS) dividing the surface of China into 2341 county level

[16] Until the "Measures on Tenders and Bids for Contracts for Construction Projects" came into effect in May 2003, competitive bidding, was recommended but not mandatory (World Bank, 2007a).

administrative units, 349 prefectures, and 33 provinces. Chinese administrative units at the county level are subdivided into county level cities (shi), counties (xian), and urban wards of prefecture level cities (shixiaqu).

County level socioeconomic records are taken from Provincial Statistical Yearbooks for the years 1990, 1997 and 2006, as well as the 1990 Chinese population census. The statistical yearbook records for 1997 and 2006 were obtained from the University of Michigan's China Data Center, and the 1990 census data as well as statistical yearbook data for 1990 were obtained from the China in Time and Space (CITAS) project at the University of Washington. The Provincial Statistical Yearbook series report county level GDP broken up into agriculture, industry, and services gross value added, as well as local government revenues and registered county populations. The 1990 Population Census provides county level data on population, education, and employment shares by sector.

These sources result in a database of 1748 historically consistent geo-referenced county units that have non-missing reporting values in the Provincial Statistical Yearbooks of 1997 and 2006 (75% of Chinese administrative units). Close to the entirety of this county sample (1706 of 1748) also report socioeconomic records in the 1990 Population Census, and 1238 of the 1748 report local government revenues in the CITAS Provincial Statistical Yearbooks for the year 1990.[17] Table 1 presents a set of descriptive statistics, and the Online Appendix describes the data sources and processing in more detail.

Geo-referenced NTHS highway routes as well as Chinese transport network data were obtained from the ACASIAN Data Center. NTHS highway routes were digitized on the basis of a collection of high resolution road atlas sources published between 1998 and 2007. These atlas sources made it possible to classify NTHS segments into three categories that coincide with the main construction phases described by the Ministry of Communications: opened to traffic before mid-1997 (10% of NTHS), opened to traffic between mid-1997 and end of 2003 (81% of NTHS), and opened to traffic after 2003 (9% of NTHS).[18] A list of the atlas publications as well as a more detailed description of the data processing and NTHS classifications is given in the Online Appendix. Finally, land cover and elevation data that are used in the construction of least cost path highway routes were obtained from the US

[17] Only a fraction of the reporting counties in 1997 and 2006 report production data in the Provincial Statistical Yearbooks for 1990.

[18] The available series of atlas sources did not allow to date the opening to traffic of each segment of the 35,000 km NTHS road network. See the Online Appendix for a listing of the atlas publications.

Geological Survey Digital Chart of the World project, and complemented by higher resolution Chinese hydrology data from the ACASIAN data center.

4 Empirical Method

I use the collection of data described in the previous section to estimate the effects of NTHS network connections among peripheral counties between 1992-2003 on changes of economic outcomes between 1997-2006. Given that 89% of the reported NTHS connections until the end of 2003 were completed during the phase of "rapid development" between 1998-2003, the main source of variation used in the estimations stems from network connections during this five year period 1998-2003 and their effects on changes of economic outcomes over the nine year period 1997-06. The baseline estimation strategy is a difference in differences specification of the form:

$$\ln(y_{ip}^{2006}) - \ln(y_{ip}^{1997}) = \alpha + \gamma_p + \beta Connect_{ip} + \eta X_{ip} + \epsilon_{ip} \ , \tag{9}$$

where y_{ip} is an outcome of interest of county i in province p, γ_p is a province fixed effect, $Connect_{ip}$ indicates whether i was connected to the NTHS between 1992-2003, and X_{ip} is a vector of control variables. I classify highway connections using GIS with a dummy indicator that takes the value of one if any part of county i is within a 10km distance of a NTHS highway that was opened to traffic before the end of 2003. Alternatively, I run specification (9) with a continuous treatment variable, $lnDistHwy_{ip}$, which stands for the logarithm of great circle distance to the nearest NTHS highway segment opened to traffic before the end of 2003, measured from the center of each county unit.

The error term ϵ_{ip} could be correlated across counties that were connected to a similar part of the network during a similar period between 1992-2003. I therefore cluster standard errors at the level of 33 Chinese provinces. Alternatively, I follow Conley (1999) and allow for spatial dependence to be a declining function over bilateral county distances without imposing parametric assumptions. Finally, due to the fact that the explicitly targeted network nodes are China's largest city regions that encompass multiple county level units, I exclude county observations within a 50 km commuting radius around the targeted city centers.[19]

[19] See Garske et al. (2011) for a study of commuting patterns and distances in China.

4.1 Least cost spanning tree networks

Estimating specification (9) by OLS would imply the assumption that county connections between nodal cities were randomly assigned within provinces. Given the policy setting of the NTHS, this assumption would be strong. The NTHS was planned in 1992 to establish the backbone of a modernized road transport system for China. Province and county governments borrowed against future expressway toll revenues to finance its construction. This background raises the concern that planners targeted politically important and economically prosperous regions on the way between the network's targeted destinations. This concern is supported by descriptive statistics presented in Table 1. Peripheral counties connected to the network by 2006 were on average larger, richer, more urbanized, and more industrialized than non-connected peripheral counties before the bulk of the network had been built in 1997.[20]

To address these concerns, I construct two hypothetical minimum spanning tree highway networks as instruments for actual route placements (see Figures 2 and 3). I refer to the first as least cost path spanning tree network, and to the second as Euclidean spanning tree network. Both instruments correspond to the question of which routes central planners would have been likely to construct if the sole policy objective had been to connect all targeted destinations on a single network in a least costly manner. The least cost path network yields more precise route predictions between any given bilateral connection on an all-China minimum spanning tree due to its use of land cover and elevation data, while the Euclidean network covers a larger set of the actually built bilateral network routes.

The least cost path network depicted in Figure 2 is constructed in a two step procedure. The first step is to compute least cost highway construction paths between all possible targeted destination pairs on the basis of remote sensing data on land cover and elevation. To this end, I adopt a simple construction cost function from the transport engineering literature that assigns higher construction costs to land parcels with steeper slope gradients and land cover classified as water, wetlands, or built structures (Jha *et al.*, 2001; Jong and Schonfeld, 2003).[21] I use the remote sensing data to create a construction cost surface covering the PR China in a rectangular grid of cost pixels (see Online Appendix for details and illustrations).

[20] Reported differences are statistically significant at the 1% level.

[21] As discussed further below, I will also include these geographical characteristics used in the construction of the instrument as direct county level controls to address the concern that these might affect changes in economic outcomes directly.

I then implement Dijkstra's optimal route algorithm to construct least cost highway construction paths between all possible bilateral city connections as well as provincial capitals and the border in border provinces. In the second step, I extract the estimated aggregate construction cost of each bilateral connection and feed them into Kruskal's minimum spanning tree algorithm. This algorithm yields the minimum number of least cost connections (i.e. number of targeted nodes minus one) to connect all targeted destinations on a single continuous network to minimize aggregate construction costs.

To construct the Euclidean spanning tree network depicted in Figure 3, the first step is to compute great circle distances between all possible bilateral connections of the network, which is done by applying the Haversine formula to bilateral coordinate pairs as well as provincial capitals and the border in border provinces. I then compute Kruskal's algorithm to identify the minimum number of edges that connect all targeted destinations subject to the minimization of total network distance. To compensate for the loss of route precision, I account for the fact that Chinese planners constructed many more than the minimum number of spanning tree connections. I therefore re-run Kruskal's algorithm within separate geographical subdivisions after dividing China into either North-Center-South or East-Center-West geographical divisions. These six additional spanning tree computations add nine bilateral routes in addition to the single all-China minimum spanning tree. The Online Appendix provides further details and additional illustrations of these computations.

4.2 Additional county controls and identifying assumption

The minimization of a network construction cost objective function from which the instruments in Figures 2 and 3 are derived is aimed to address the concern of non-random highway placements on the way between targeted destinations. However, the exclusion restriction could be violated if locations along least cost road construction paths between major economic centers in China are correlated with economic county characteristics due to history and sorting. Furthermore, the instrument is likely to be mechanically correlated with distance to the nearest targeted metropolis. I therefore estimate regressions before and after including a set of additional county controls that could be correlated with the instrument while also affecting the change of economic outcomes between 1997-2006.

Counties closer to targeted city centers are mechanically more likely to lie on a least cost spanning tree path than counties situated farther away. Concerns about the exclusion restriction arise if distances to the major cities of China are correlated with economic county characteristics that also affect growth trajectories. I include the log distance between counties and the nearest targeted metropolitan city center to address this concern.

Conditional on county distance to the targeted centers, location on least cost road construction paths between major economic centers in China could be correlated to political and economic county characteristics due to historical trade routes. To address such concerns, I include a set of observable controls for pre-existing county level political status and economic conditions. The two political controls are dummy variables indicating whether the county seat was a prefectural capital or has city as opposed to township status in 1990. The concern is that higher administrative status might be historically concentrated along least cost path routes between important economic centers.

Concerning pre-existing economic conditions, I use data from the 1990 Census at the county level which allows me to compute the share of agricultural employment in total county employment, the logarithm of county level urban registered population, as well as the share of above compulsory schooling attainment in total county population above 20 years of age in 1990.[22] These controls are aimed to address concerns that counties along least cost connections between major cities differ in terms of both their economic composition (shares of skilled labor and sectoral specialization), as well as in their mass of economic activity (urban populations).

The baseline identifying assumption is that county location along an all-China least cost spanning tree network affects changes in county level economic outcomes only through NTHS highway connections, conditional on province fixed effects, distance to the nearest targeted city region, administrative status and county-level economic conditions in 1990. I address a series of robustness checks after reporting baseline estimation results.

[22] Categories beyond the compulsory 9-year curriculum are senior middle school, secondary technical school, technical college, junior college and university.

5 Estimation Results

5.1 Average network connection effects

This subsection reports the empirical results and robustness checks on Propositions 1 and 2 of the theory section. Table 2 presents the first stage results for the least cost path and the Euclidean network instruments as well as their combined first stage results. First stages are run for binary NTHS connection indicators as well as the log distance to the nearest NTHS segment. Both the least cost path and the straight line networks are strongly significant within province predictors of actual NTHS placements conditional on log distance to the nearest targeted node and the full set of pre-existing political and economic county characteristics. County controls are related to NTHS exposure mostly as expected. NTHS route connections are more likely for counties with lower distances to the targeted metropolitan city centers, larger pre-existing urban populations, and city status.[23]

Both instruments remain statistically significant when included simultaneously, confirming that the two spanning tree networks capture slightly different sources of the increased likelihood of route placements. While the least cost path instrument is a more precise predictor of placements on any given bilateral connection, the Euclidean tree instrument captures a higher proportion of the actually built network connections.

Table 3 presents OLS and IV results when regressing log changes of county level outcomes on the binary network treatment variable before and after including the full set of 1990 county controls. The Online Appendix reports results after replacing the binary network treatment with the log county distance to the nearest NTHS segment. The results discussed in this section are confirmed (in opposite sign as expected) in these continuous NTHS connection specifications.

The instrumental variable estimates of the NTHS connection effect in Table 3 are negative and statistically significant for industrial output growth, non-agricultural output growth, local government revenue growth, as well as total GDP growth. Two important patterns emerge. The first is that the OLS point estimates are less negative than the IV estimates.

[23] When individually included, higher pre-existing shares of agricultural employment decrease the likelihood of route placements, and higher shares of educated population increase it. These correlations are no longer significant when both controls are added simultaneously as reported in Table 2. Finally, the identifier for prefecture level capital status in 1990 enters in opposite sign than expected (decreased likelihood). This is due to the simultaneous inclusion of the city identifier, so that the coefficient is driven by approximately 1% of relatively remote prefecture level capitals that are not also classified as cities in 1990.

The second is that the inclusion of additional county controls for pre-existing political status and economic conditions leads to more negative point estimates of the NTHS connection effect.

The first of these is in line with the discussed concern that planners targeted places with higher expected returns to infrastructure investments and/or higher expected traffic demand, which is also apparent in the descriptive statistics of Table 1. The second attests the conditionality of the exclusion restriction on controlling for pre-existing political and economic county differences. The results in Table 3 suggest that county location along least costly road construction paths between major cities in China is at least partly correlated with pre-existing county characteristics, such as the size of urban populations, the share of educated labor, and the degree of industrialization. As noted in the previous subsection, these correlations could be driven by settlements and sorting along historical trade routes. However, the finding that conditioning on pre-existing county differences leads to more negative connection treatment effects on industrial output growth, total output growth, as well as local government revenue growth suggests that these characteristics are positively associated with economic growth, rather than negatively.

Nevertheless, the sensitivity of the IV point estimates to the inclusion of county controls in principle raises the concern that the estimated effects remain biased in either direction due to omitted unobserved differences that are correlated with the instrument. A related concern is that counties along an all-China spanning tree network had different pre-existing growth trends before the highway network came into effect. To address such concerns, I make use of the fact that the majority of the reporting county sample in 1997 and 2006 also reported local government revenues in the Provincial Statistical Yearbooks for the year 1990. If the exclusion restriction is satisfied conditional on the included county controls, then we should expect to find no significant relationship between NTHS treatments and local government revenue growth prior to the network, when estimated on the identical county sample for both periods.

Table 4 presents OLS and IV results for both instruments in both periods 1990-1997 and 1997-2006. For completeness, the table also reports results for the continuous NTHS exposure variable measured by the log county distance to the nearest NTHS route for both periods. The county sample is smaller than in the previous regressions firstly because not all reporting counties in 1997-2006 have non-missing entries for local government revenue in 1990, and secondly because these regressions exclude counties that were connected to NTHS routes built between 1992-1997 (10% of the NTHS).

The connection indicator enters negatively and statistically significantly only for the NTHS period, and the log distance to the nearest NTHS segment enters positively and statistically significantly only for the NTHS period. Furthermore, these outcomes are not driven by differences in the size of the standard errors of the point estimates across the two different periods, but by changes in the point estimates themselves. These results provide a reassuring robustness check of the exclusion restriction conditional on the included set of pre-existing political and economic county controls. A series of additional robustness checks will be discussed at the end of this subsection, and the following subsection tests the model's predictions on the heterogeneity of the NTHS connection effects.

According to second stage IV results using both spanning tree instruments and the full set of county controls as reported in the final column of Table 3, NTHS connections on the way between targeted destinations have on average reduced GDP growth by about 18 percent over a nine year period between 1997-2006 compared to non-connected peripheral counties. Local government revenue growth is reduced by approximately 23 percent. These adverse growth effects appear to be mainly driven by a decline in industrial output growth of approximately 26 percent over the nine year period.[24]

Results in Table 3 for agricultural GDP growth are close to zero and not statistically significant. This finding is in contrast to the model's prediction about the reallocation of labor from industry to the agricultural sector. This result could be due to labeling both more and less industrialized activities as agricultural in county level economic accounts. An economic explanation of this finding could be related to factor market rigidities or adjustment costs and the frequent empirical finding that the inter-sectoral reallocation of resources following trade shocks fails to be confirmed in the data (Goldberg and Pavcnik, 2007).

The final result from Table 3 is that NTHS connections had no effect on county population growth. The point estimates are close to zero and statistically insignificant conditional on controls. This result is consistent with the above discussion of Chinese migration controls and suggests that the stated output growth effects are not driven by significant differences

[24]The cited estimates correspond to point estimates as shown in the regression tables after converting log points back to percentage changes and rounding.

in population growth across counties. The following subsection on the interaction effects of NTHS connections also addresses a further robustness check concerning the possibility of unreported outmigration that could remain uncaptured when estimating the NTHS effect on registered county populations.

In addition to the results reported in this section, the Online Appendix includes a series of additional robustness checks concerning the average NTHS connection effects on production and government revenue growth. These address concerns about i) controlling for potential direct effects of the land cover and elevation characteristics used in the construction of the least cost path instrument, ii) adjusting standard errors for spatial dependence following Conley (1999) instead of province level clustering, iii) controlling for construction activity already underway in 1997, iv) excluding mountainous regions due to least cost path endogeneity concerns, v) excluding the Golmud-Lasa railway route completed over the same period, and vi) controlling for proximity to historical trade routes such as the Silk Road. The results discussed in this section are robust in their magnitude and statistical significance in these additional specifications.

The Online Appendix also provides a discussion and estimation results concerning the proportion and observable characterization of the complier group of counties that drive the estimated local average treatment effects. Descriptive statistics and the pattern of coefficient estimates discussed above suggest that planners targeted economically prosperous counties on the way between targeted city regions. The additional estimations address the concern that least cost spanning tree location might have affected actual highway placements only for a subset of remote and economically stagnant counties on the way between targeted nodes, so that the estimated local average NTHS connection effects might systematically differ from population average effects. The results presented in the Online Appendix provide evidence against this concern, showing that the predictive power of the instruments does not significantly vary across observable pre-existing county characteristics. The reasons behind this finding are linked to the nature of the spanning tree prediction errors compared to actual NTHS route placements which are further explored in reference to a set of cartographic illustrations.

5.2 Interaction effects and alternative channels

This subsection reports the empirical results and robustness checks on Propositions 4 and 5 of the theory section. To test the model's additional predictions on the heterogeneity of the network's effects among non-targeted peripheral counties, I estimate specification (9) after including interaction terms between the NTHS connection indicator and the county log distance to the nearest targeted metropolitan node, as well as an indicator for counties with above mean 1990 total employment sizes. The log distance to the nearest metropolitan node is aimed to capture the initial degree of trade freeness between core and periphery (Proposition 3). The categorization of large counties in terms of 1990 employment sizes is aimed to capture the pre-existing degree of the core-periphery size differential (Proposition 4). Alternatively, the binary NTHS connection indicators in these interactions are replaced by the continuous treatment variable $lnDistHwy_{ip}$ as in the previous subsection.

Table 5 reports second stage least squares results for industrial output growth as well as aggregate GDP growth as dependent variables after instrumenting for NTHS connection and its interaction terms with the least cost path network instrument.[25] The first column for each dependent variable reproduces the average treatment estimate conditional on the full set of county controls as reported in Table 3. The second columns then introduce the additional two interaction terms. In the binary network connection specifications both interaction terms enter positively and statistically significantly for both industrial and aggregate output growth. When using the log distance to the nearest NTHS segment as continuous treatment variable instead, the interaction terms enter negatively and statistically significant for both dependent variables.

A potential concern with these two stage least squares results is that the first stage F-statistics significantly drop after instrumenting for NTHS treatments as well as its interactions. The Online Appendix reports an additional set of results that compare two stage least squares (2SLS) estimates using both instruments to estimations by limited information maximum likelihood (LIML). The fact that the variation of first stage F-statistics between the different specifications across Columns 2-4[26] in Table 5 have little effect on the point estimates

[25] In the cross-derivative regressions the least cost path spanning tree instrument performes better in terms of first stage predictive power than the Euclidean instrument or both instruments combined. The Online Appendix reports these specifications using both instruments instead.

[26] The final column is not estimated on the identical county sample.

of the two interaction terms of interest, and the fact that the reported LIML point estimates are slightly higher than the 2SLS estimates reported in the Online Appendix indicate that weak instrument bias is unlikely to be a concern.[27]

The reported results provide empirical evidence for significant heterogeneity in the NTHS connection effects among peripheral counties that confirms the additional cross-derivative predictions of the model. In particular, while the majority of both large and small peripheral counties are estimated to have experienced negative GDP growth effects, a subset of large peripheral counties that are also subject to large initial trade costs with respect to the targeted metropolitan city centers are estimated to have experienced positive growth effects due to NTHS connections.[28]

In the following, I consider the interaction effects of peripheral NTHS connections in the light of alternative channels. While the reported negative average effects on not just sectoral but aggregate output growth are *a priori* difficult to reconcile in absence of the home market channel, one might nevertheless be concerned that the observed average effects and their interactions are partly driven by alternative microeconomic channels.

A first remaining concern could be that county size and/or distance to the nearest city center are correlated with relative production costs across counties linked to neoclassical channels of trade. In particular, relative cost (dis-)advantages in industrial production could be correlated with these characteristics. Columns 3-5 in Table 5, report results after including a series of additional interaction terms with respect to pre-existing political and economic county characteristics. Reported estimates now control for the heterogeneity of the NTHS connection effect on county level industrial or aggregate output growth with respect to 1990 differences in the share of skilled population, the share of agricultural employment, county political status as a city or a prefecture level capital, and local government revenue per capita. These additional interaction terms are aimed to capture differences in relative factor prices or technologies across counties that could be correlated to market size or distance to the nearest targeted city regions.

The finding that the estimates on the interactions between NTHS treatments and metropolitan proximity and county size are confirmed in statistical significance is reassuring. Further-

[27]See for example Angrist and Pischke (2008, Section 4.6) for a discussion 2SLS and LIML estimates in the context of weak instrument concerns.

[28]The median and mean distances to the nearest trageted city node were 168 km and 203 km respectively.

more, the point estimates of these coefficients are hardly affected by the inclusion of the additional interaction terms across Columns 3-5. This provides support for the interpretation that the estimated reduced form effects are driven by the home market channel, rather than capturing alternative relative cost determinants of integration.

A second remaining concern could be that NTHS connections have reduced the costs of unregistered outmigration to larger metropolitan markets. Despite the fact that we find no significant migration response from registered population records, one could suggest that unregistered outmigration happens on a large scale and is significantly affected by NTHS network connections. The negative growth effects in this setting could then be driven by an unregistered reduction in employment which reduces both industrial production and GDP. To assess this explanation against the proposed theoretical channel, I consider the interaction effects of NTHS connections that would arise under such a channel.

The concern would be that unregistered migrants move to equalize real wages across counties net of the costs of migration, metropolitan centers have higher real wages, and NTHS connections tip the balance for a larger number of peripheral citizens to outmigrate compared to non-connected counties. Similar to the alternative channels considered above, a testable distinction compared to the home market channel is that interaction effects should be driven by regional factor returns, and not by market size or the initial trade cost position. In particular, one would expect the interaction point estimates with respect to county size and metropolitan distance to be sensitive to the inclusion of the additional interaction with respect to the log of local government revenue per capita reported in 1990 which serves as a proxy for regional income per capita differences.[29] The results reported in Table 5 prove robust to the concern of large scale unregistered outmigration responses.

6 Structural Estimation And Results

The first objective of this section is to assess to what extent the Helpman-Krugman microfoundation of the home market effect can quantitatively account for the observed reduced form effects. To this end, I calibrate the model to fit the county level distribution of industrial activity in 1997, and simulate the network's effects subject to observed reductions in bilateral county trade costs from Chinese transport network data. I then document simulation

[29] Only a fraction of counties reporting in 1997-2006 reported GDP in the Provincial Statistical Yearbooks for 1990.

results across a wide range of parameter combinations to assess the robustness of the qualitative predictions from the stylized three-region model in the full multi region setting, and characterize the parameter space that best accounts for the observed reduced form effects. The second objective is to use the best fitting parameterization of the structural model in counterfactual policy estimations to learn about the network's effect on the concentration of economic activity in China as well as its welfare implications.

6.1 Calibration and simulation

6.1.1 Calibration to 1997 distribution of industrial production

The profit equation in (5) coupled with capital return equalization and the restriction that regions retain some positive fraction of production in both sectors yield a system of R equations that can be solved for an $R*1$ vector of regional industrial production shares as a function of an $R*R$ bilateral trade cost matrix and an $R*1$ vector of initial expenditure shares which are in turn determined by endowment shares as presented in (6).

Given 1997 levels of bilateral trade freeness parameters, $\tau^{1-\sigma} = \phi$, and the observed 1997 county level distribution of industrial output, I can calibrate unobserved county level expenditure shares to fit the distribution of observed industrial activity before the majority of the NTHS network were built.[30] One advantage of this calibration approach is that the calibrated regional expenditure shares will capture not just domestic market access, but also county level differentials in cross-border market access as the observed distribution of industrial activity in 1997 reflect the sum of effective market access.

To be able to compute the 1997 expenditure share vector, one needs to compute the pre-existing matrix of bilateral trade costs. I follow the standard approach from the gravity literature in international trade and model initial levels of transport costs as a function of bilateral distance between two counties j and k, $\tau_{jk} = D_{jk}^{\delta}$. This approach requires two parameter choices in the calibration exercise. The first parameter is the elasticity of transport costs with respect to distance (δ). The second parameter is the elasticity of substitution between varieties (σ). The choices of these two parameters jointly determine the distance elasticity of trade between bilateral county pairs: $\delta(1-\sigma)$. As described below, I consider a wide range of parameter combinations.

[30] Regional expenditure shares are the sum of immobile labor income and returns to immobile owners of mobile capital.

The two parameter choices allow me to compute the $R * R$ matrix of bilateral trade freeness parameters on the basis of great circle distances between all bilateral county pairs. Combined with the observed initial distribution of county level industrial activity, this allows me to calibrate the model to fit the pre-existing county level distribution of industrial activity and compute the vector of pre-existing expenditure shares.

Counties with 1997 statistical yearbook observations on industrial output yield an all-China estimation sample of 1679 regions. In line with the empirical analysis presented above, each of the 54 targeted metropolitan city regions have been aggregated to a single region encompassing a 50 km commuting buffer around the city center. The 1679 estimation sample thus contains 54 targeted city regions, and 1625 non-targeted peripheral regions.

6.1.2 Simulation of NTHS effects subject to observed trade cost reductions

Given initial bilateral trade costs and the initial county vectors S_Y and S_N, I can simulate county level economic changes due to the NTHS system subject to observed bilateral trade cost changes. To estimate the $R*R$ matrix of bilateral trade cost changes due to the addition of new NTHS routes, I use road network data provided by the ACASIAN data center to create a geographical information system of China's primary and secondary road network for mid-1997 (before the bulk of expressways were built) and at the end of 2003 (after the bulk of the expressway network was built).[31] This allows me to apply a minimum cost routing algorithm on both network datasets to extract bilateral transport cost measures between all possible bilateral county pairs before and after the network was built.

I model the trade cost reduction effects of new NTHS route additions in terms of bilateral transport cost percentage changes that I can compute from the GIS network database and the optimal routing algorithm. In theory, new route additions will affect the iceberg trade costs τ_{jk} in the trade freeness parameter $\phi_{jk} = \tau_{jk}^{1-\sigma}$. Iceberg trade costs imply that $(\tau_{jk} - 1)$ units of industrial varieties are used up in transport between any given bilateral pair, so that $(\tau_{ij} - 1)$ is the ad valorem trade cost between counties. I use the estimated percentage reduction in bilateral transport costs from the network analysis to obtain an estimate of the

[31] The Online Appendix provides an illustration of the road network used in the computation. The present analysis abstracts from railroad transport, air transport and inland waterways mainly to avoid the need to parameterize relative per km transport costs across modes, and as a changing function over distance for rail, air, and waterways. According to national transport statistics provided by the Chinese National Bureau of Statistics for the year 2000, 77% of Chinese domestic freight was accounted for by road transport (www.stats.gov.cn/english). Since waterways and railways are used for higher weight-to-value ratios, this percentage is likely a lower bound estimate of the relative importance of road transport in domestic trade.

change in $(\tau_{jk} - 1)$ between any bilateral county pair.[32]

The network routing analysis to compute bilateral percentage transport cost changes requires assumptions about the relative per kilometer cost of transport across different road types in China. In absence of empirical estimates of these parameters across Chinese provincial highways, national highways, and the new NTHS expressways, I take the relative reported speed limits as my baseline estimation. This choice reflects the empirical finding in, for example, Combes and Lafourcade (2005) that time varying costs of road transport, such as drivers' wages, account for a substantial part of total transport costs. Given speed limits of 120 km/h, 100 km/h, and 80 km/h for NTHS expressways, national highways, and provincial highways respectively, the baseline per km cost ratios when choosing national highways as the reference point are approximately 0.85 for NTHS routes, 1 for national highways, and 1.25 for provincial highways. To address the empirical uncertainty of this baseline estimate, each simulation will be run across a band of five equally spaced alternative parameterizations that are centered around the baseline estimate as further discussed below.

These relative per kilometer trade cost parameters are attached to network arcs of different road types in the GIS road network dataset of China both before and after the additional NTHS expressway connections were added over the period 1997-2003. The minimum cost routing algorithm produces bilateral network transportation costs subject to the original network in 1997 (with 10% of the NTHS completed) and subject to the network at the end of 2003 (with 81% of the NTHS completed). The resulting matrix of bilateral percentage cost reductions are then used to compute the $R * R$ matrix of bilateral trade freeness parameters for the post-NTHS network. Given the calibrated S_Y vector and the post-NTHS trade cost matrix, equation (5) yields a system of R equations in R unknown post-NTHS industrial production share outcomes. The solution to this S_N vector of simulated post-NTHS county industrial production shares then yields results for simulated industrial output growth at the county level.

6.1.3 Parameter ranges and number of simulations

The choice parameters for calibrations and simulations are the elasticity of trade costs to distance (δ), the elasticity of substitution between industrial varieties (σ), which together

[32] Denoting total bilateral transport costs as TC_{jk}, ad valorem bilateral transport costs for a given industrial variety between bilateral county pair j and k are $(\tau_{jk} - 1) = \frac{TC_{jk}}{p}$, so that $\frac{d(\tau_{jk}-1)}{\tau_{jk}-1} = \frac{dTC_{jk}}{TC_{jk}}$.

determine the trade cost elasticity of trade ($\delta(1-\sigma)$). In addition, I estimate simulated results for each parameter combination across a range of five parameterizations for the relative per km cost of NTHS routes relative to existing national highways that is centered around the baseline estimate of 0.85. These range from 0.75-0.95 and are equally spaced in deviations of 0.05.

I consider a wide range of parameter combinations with respect to δ and σ, allowing δ to vary between 0.2-1.6 in intervals of 0.02 and allowing σ to vary between 2-10 in intervals of 0.2. Each of these 71*41=2911 simulations is computed across the five alternative parameterizations of relative NTHS transport cost savings. Each of these single simulations yields a vector of simulated county level changes of industrial activity across the 1679 regions.

6.2 Quantitative assessment of the home market channel

The first question of this subsection is how robust the qualitative predictions from the three region policy scenario are in the full multi-region setting with observed bilateral trade cost changes. Figure A.1 depicts regression coefficients for simulated county industrial output growth on the binary NTHS connection treatment dummy estimated for the identical peripheral county sample for which reduced form estimation results are reported in Table 3. The point estimates are derived from the identical regression specification including the full set of 1990 county level controls and province fixed effects. The OLS point estimate of each separate vector of county level simulation results is plotted against the trade elasticity parameter implied by the combinations of δ and σ.[33] The horizontal line indicates the preferred instrumental variable estimate displayed in the final column of Table 3.

The first point to note is that the prediction of a negative NTHS connection effect among peripheral counties (Proposition 1) is confirmed in the full multi-region setting subject to observed trade cost changes. Not surprisingly, for prohibitively high initial cross-county trade costs, NTHS induced trade cost reductions have zero effect on industrial output growth differences between connected and non-connected peripheral counties. Once the initial level of trade costs in the system drops below prohibitive, the home market channel is at work and the core-periphery prediction of the model becomes stronger the lower the initial level of trade costs.

[33] All displayed results correspond to the baseline parameterization of the relative transport cost savings on NTHS routes compared to existing national highways.

Figure A.2 shifts attention from the predicted average connection effect among peripheral counties to its predicted heterogeneity with respect to pre-existing county characteristics (Propositions 3 and 4). The y-axis displays the difference of simulated average connection effects on industrial output growth between county groups with above and below mean distance to the nearest targeted node, and with above and below mean employment size in 1990. Connection effects are estimated from four separate regressions of simulated outcomes on the NTHS connection dummy and province fixed effects. The x-axis displays the range of trade cost elasticities that yield results in the proximity of the reduced form average connection effect displayed by the horizontal line in Figure A.1. In confirmation of the cross-derivative predictions of the three-region model and the reduced form results presented in Table 5, the NTHS effect is predicted to be more negative among smaller peripheral counties and lower initial trade costs to targeted metropolitan cities.

The second question of this subsection concerns the quantitative performance of the model's home market channel in accounting for the estimated reduced form treatment effects from the IV estimations. To this end, I implement a two-stage parameter grid search across all simulation results. In the first stage, I identify all parameter combinations for which the estimated average treatment effect is statistically significant at the 10% level and within half a percentage point of the estimated reduced form treatment effect from the identical specification and the identical county sample reported in the final column of Table 3. In the second step, I further limit the selection to simulations with statistically significant (10% level) and positive interaction effects with respect to distance to the nearest targeted node and 1990 employment size, and compute the sum of squared deviations of simulated interaction effects from those reported in Column 2 of Table 5. The two-stage procedure places higher weight on matching the average observed connection effect of the network before further selecting on the basis of its heterogeneity across counties.

These narrow search criteria yield three best fitting parameter combinations that are reported in Table 6. The first point to notice is that the best fitting parameter combinations are clearly within the range of commonly found empirical estimates for both the elasticity of substitution and the implied trade elasticity to distance. For the best fitting parameter combination, these respective values are 2.4 and -1.6. For example Redding and Sturm (2008) have obtained the identical parameter estimate of the trade elasticity to distance also in the context of land based transport for German regions. Secondly, the best fitting parameterizations are based on the same baseline estimate of relative transport costs of new NTHS expressways relative to existing national highways. Given that the estimate is based on relative travel times, this is in line with existing empirics on the importance of time costs in road transport.[34]

Finally, the best fitting parameter space depicts a trade off between the two choice parameters that together determine the trade elasticity over distance. Figure A.3 displays the relationship between the trade cost elasticity to distance and the elasticity of substitution when conditioning on the parameter space that yields statistically significant and close to identical average connection effects compared to the IV point estimates in the final column of Table 3. Similar to the findings in Redding and Sturm (2008), the apparent trade off between the two parameters that jointly determine the elasticity of trade to distance suggests that the latter is the binding parameter that governs the model's prediction on the intensity of the effects of a given trade cost shock.

6.3 Counterfactual policy estimations

The final part of the paper uses the best fitting parameterization of the calibrated structural model for the purpose of counterfactual policy estimations. Table 7 presents regression results of simulated industrial output growth on an identifier variable for targeted metropolitan city regions before and after including province fixed effects. While the identification strategy of the preceding empirical analysis was based on variation of highway connections among non-targeted peripheral counties, the structural model allows to analyze the network's effects across the all-China county sample. The model suggests that the NTHS network had a significantly negative average growth effect among all peripheral counties in China, whereas a small but statistically significant positive effect is the case for targeted metropolitan centers.

Table 8 presents estimation results on changes of industrial concentration as measured by a Herfindahl index for the all-China county sample as well as for within peripheral or within metropolitan county groups. Following from the results discussed up to this point, the NTHS is found to have increased the concentration of industrial activity in China. Interestingly, the model suggests that industrial concentration has increased most within the peripheral county

[34] See for example Combes and Lafourcade (2005).

group. The first reason is that peripheral regions constitute a more homogenous group prior to the network so that differential output growth rates across counties have a stronger effect on industrial concentration within this group.[35] The second reason is that, as indicated by the estimation results on Proposition 5, initially larger peripheral counties were affected more positively by new highway connections within the Chinese periphery.

Finally, the structural model can help to shift attention from nominal output growth to county level price index consequences. In the Helpman-Krugman model gains from trade arise purely from increased regional consumer access to industrial varieties captured by the ideal price index.[36] Given preferences in (1), the ideal price index for region j is given by:

$$P_j = \left(\sum_k \phi_{jk} S_{Nk} \right)^{\frac{-\mu}{\sigma-1}} \tag{10}$$

where μ is the expenditure share of industry in consumption. Applying the best fitting parameter combination identified in Table 6 to parameterize σ and the matrix of initial bilateral ϕ_{jk}'s, and including an observed household expenditure share on non-agricultural merchandise of $\mu = 0.5$ from the Chinese input-output table in 2000, I can estimate county level price indices according to (10) on the basis of observed industrial output shares (S_{Nk}) in 1997, as well as for simulated industrial output shares after the NTHS was built.

Table 9 presents OLS regression results for simulated price index changes. The estimated population weighted county level average price index reduction due to the construction of the NTHS network is -1.1% across all counties in China. Evaluated at nominal Chinese GDP in the year 2000, the model thus predicts substantial NTHS induced gains from trade of 10% in annual terms of the total officially stated network construction costs (120 billion US dollars).

Columns 3 and 4 then shed light on the welfare distributional predictions of the parameterized model. The first point to notice is that all county groups are predicted to have benefited from the NTHS in terms of local price index reductions for industrial varieties. This finding is a result of two counteracting forces among peripheral counties. On average, peripheral counties are predicted to have experienced reductions of industrial output growth

[35] In contrast, even strongly reduced peripheral output growth has a minor effect on a national index of Chinese industrial concentration because of the small pre-existing relative mass of industry that peripheral counties represent relative to the metropolitan regions.

[36] As discussed in the theory section, nominal wages and capital returns are invariant to trade cost changes. Repatriation of returns to mobile capital and costless reallocation of labor to the freely traded numeraire sector imply that local price index changes represent a sufficient welfare statistic in the model.

which adversely affects the local price index (to increase). On the other hand, peripheral counties have gained access to the mass of metropolitan industrial varieties that is many times larger than their individual shares of production. The predicted net result of these two forces is that all counties have benefited from greater access to industrial varieties.

The second point is that the group of connected peripheral counties who have experienced the largest adverse production effects is also the group with the highest predicted average price index reductions. The important insight of the structural model is that the observed increase in the concentration of industrial and aggregate economic activity does not necessarily imply parallel welfare distributional effects across regions. The reason is that small peripheral production centers obtain cheaper access to the bulk of the industrial production mass located in the core production regions, so that the effect on local price indices is likely to be strongest for the connected periphery.

In contrast to the network's effects on county level economic activity, the absence of data on local price indices and household incomes in Provincial Statistical Yearbooks prevents the comparison of the model's predictions to reduced form empirical evidence on the NTHS welfare effects. In this context, it is important to underline that the model's welfare predictions abstract from other potential channels of gains from trade, such as comparative advantages or productivity effects on one side, and on the other side abstract from potential impediments to the estimated gains such as factor reallocation costs or decreasing returns to scale in agriculture. While the counterfactual estimations of the model provide important additional insights, the absence of supporting reduced form evidence should serve as a cautionary note against firm conclusions on the welfare effects.

7 Conclusion

Increasing returns to scale trade theory makes important predictions about the consequences of trade integration between regions with uneven market sizes. The home market effect in Krugman (1980) and Helpman and Krugman (1985) provided a microfoundation for the proposition that market size is a determinant of industrialization. The same channel also suggests that falling trade costs between asymmetric regions can reinforce the concentration of economic activity. This paper exploits China's NTHS as a source of plausibly exogenous variation in trade cost shocks across a large number of *ex ante* asymmetric regions to test for the role of market size in trade integration.

The paper presents evidence in favor of the home market channel of trade integration. The presented findings provide two novel insights. First, the paper presents evidence in favor of the hypothesis that market integration can reinforce the concentration of economic activity. Second, the paper presents a novel empirical test of the home market effect using a very different setting and source of variation compared to existing literature. These findings are in support of theoretically motivated policy discussions in the trade literature (Fujita *et al.*, 1999; Baldwin *et al.,* 2003), and serve to emphasize the importance of potentially unintended general equilibrium consequences when evaluating and planning large scale transport infrastructure policies.

The counterfactual estimations of the calibrated structural model also allow to shed light on a set of economic consequences that are outside the scope of reduced form estimation. In particular, the model suggests that the network led to significant aggregate welfare gains from trade, and illustrates an important distinction between the nominal and real distributional consequences across regions. Because connected peripheral regions gain access to the mass of industrial varieties produced in the metropolitan regions, the estimated consumer price index reductions suggest that the increased concentration in nominal production does not foretell parallel welfare distributional effects. The latter insight serves to emphasize caution when drawing welfare conclusions from observed changes to the regional distribution of nominal production.

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Figures (for inclusion in text)

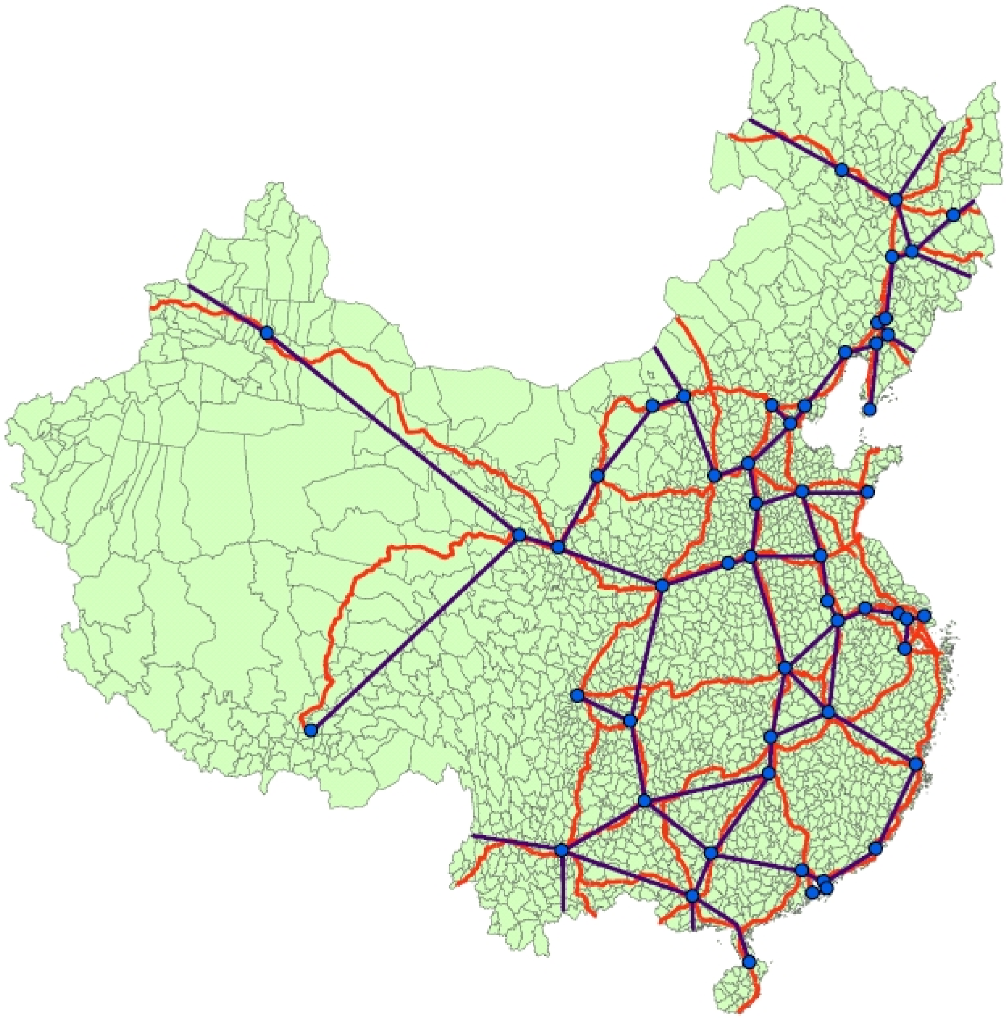
Figure 1: China's National Trunk Highway System

The figure shows Chinese county boundaries in 1999 in combination with the 54 targeted city nodes and the completed expressway routes of the National Trunk Highway System (NTHS) in the year 2007.

Figure 2: Least cost path spanning tree network

The network in red colour depicts the completed NTHS network in 2007. The network in black colour depicts the least cost path spanning tree network. The black routes are the result of a combination of least cost path and minimum spanning tree algorithms. In the first step Dijkstra's (1959) optimal route algorithm is applied to land cover and elevation data in order to construct least costly paths between each bilateral pair of the targeted centers. In the second step, these bilateral cost parameters are fed into Kruskal's (1956) minimum spanning tree algorithm to identify the minimum number of bilateral routes that connect all targeted cities on a single continuous network of the PR China to minimize total route construction costs. Border connections are least costly paths between provincial capitals to the border in border provinces. A detailed description of these computations and additional maps can be found in the Online Appendix.

Figure 3: Euclidean spanning tree network



The network in red colour depicts the completed NTHS network in 2007. The network in purple colour depicts the Euclidean spanning tree network. The routes are the result of applying Kruskal's (1956) minimum spanning tree algorithm to bilateral Euclidean distances between targeted nodes. This algorithm is first run for the all-China network, and then repeated within North-Center-South and East-Center-West divisions of China. These repetitions add 9 routes to the original 53 bilateral connections. Connections between provincial capitals of border provinces and the border are minimum Euclidean distance paths. A detailed description of these computations and additional maps can be found in the Online Appendix.

Tables (for inclusion in text)

Table 1: County level descriptive statistics for 1997

	Targeted City Centers	Connected Periphery	Non-connected Periphery	National Share of Targeted City Centers
Population (10,000)	233.24	56.96	38.48	0.14
Urban population (10,000)	179.69	10.77	5.83	0.44
GDP (100 Million Yuan)	517.86	32.58	15.09	0.42
GDP per capita (Yuan)	21435.06	5142.16	3637.09	-
Local government revenue (100 Million Yuan)	38.23	1.23	0.57	0.60
Industrial gross value added (100 Million Yuan)	194.61	14.93	5.58	0.39
Non-Agricultural gross value added (100 Million Yuan)	505.75	24.42	9.74	0.50
Agricultural output share	0.04	0.34	0.42	-
Land area (km²)	1543.09	3057.47	4513.40	0.013
Number of counties	54	424	943	54

The first three columns present mean 1997 levels, and the fourth column presents national shares by county groups. Targeted city centers refer to the central city county units (shixiaqu) of targeted metropolitan regions. Peripheral counties are counties outside a 50 km commuting buffer around the targeted city centers.

Table 2: First stage regressions

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable:	Connect	Connect	Connect	lnDistHwy	lnDistHwy	lnDistHwy
Least Cost Path IV	0.323***		0.254***	0.317***		0.245***
	(0.0574)		(0.0635)	(0.0645)		(0.0635)
Euclidean IV		0.243***	0.144**		0.280***	0.193***
		(0.0529)	(0.0560)		(0.0599)	(0.0657)
lnDistNode	-0.130***	-0.127***	-0.104***	0.588***	0.635***	0.426***
	(0.0376)	(0.0295)	(0.0323)	(0.130)	(0.112)	(0.122)
Prefect Capital	-0.124*	-0.129*	-0.120*	0.437**	0.429*	0.413*
	(0.0648)	(0.0736)	(0.0658)	(0.209)	(0.229)	(0.215)
City Status	0.0891**	0.0929**	0.0847**	-0.297***	-0.296***	-0.270***
	(0.0403)	(0.0437)	(0.0399)	(0.0946)	(0.103)	(0.0951)
lnUrbPop90	0.106***	0.115***	0.107***	-0.228***	-0.244***	-0.227***
	(0.0225)	(0.0217)	(0.0209)	(0.0691)	(0.0640)	(0.0636)
Educ90	-0.273	-0.303	-0.302	-1.671	-1.747	-1.626
	(0.598)	(0.656)	(0.601)	(1.697)	(1.804)	(1.666)
AgShare90	-0.170	-0.216	-0.167	0.0238	-0.00173	-0.0160
	(0.182)	(0.189)	(0.179)	(0.537)	(0.555)	(0.533)
Constant	-0.212	-0.314	-0.388	2.321**	2.627**	2.695**
	(0.335)	(0.299)	(0.293)	(1.103)	(1.049)	(0.992)
Obs	1342	1342	1342	1342	1342	1342
R^2	0.222	0.204	0.233	0.401	0.394	0.414
First stage F-Stat	31.61	21.07	20.31	24.09	21.82	15.00

All regressions include province fixed effects. Columns 1-3 report results for binary NTHS connection indicators among peripheral counties. Columns 4-6 report results for the log distance to the nearest NTHS segment among peripheral counties. lnDistNode is log county distance to the nearest targeted city node. Prefect Capital and City Status are binary indicators for respective county status in 1990. lnUrbPop90 is log 1990 county urban population. Educ90 is the 1990 county share of above compulsory schooling in 20+ population. AgShare90 is the 1990 county share of agricultural employment. Standard errors are clustered at the province level and stated in parentheses below point estimates. ***1%, **5%, and *10% significance levels.

Table 3: Testing Propositions 1 and 2 on average effects of peripheral network connections

Dependent Variables		(1) OLS No Controls	(2) OLS With Controls	(3) LCP IV No Controls	(4) LCP IV With Controls	(5) Euclid IV No Controls	(6) Euclid IV With Controls	(7) Both IVs No Controls	(8) Both IVs With Controls
	Connect	-0.0529	-0.0356	-0.284**	-0.304**	-0.246*	-0.287*	-0.272***	-0.297***
Change ln(IndGVA)		(0.0418)	(0.0499)	(0.118)	(0.145)	(0.148)	(0.154)	(0.0965)	(0.108)
1997-2006	Obs	1302	1280	1302	1280	1302	1280	1302	1280
	R^2	0.242	0.255						
	Connect	-0.0411	-0.0266	-0.243**	-0.252**	-0.270**	-0.296**	-0.251***	-0.268***
Change ln(NonAgGVA)		(0.0335)	(0.0375)	(0.0983)	(0.117)	(0.122)	(0.131)	(0.0877)	(0.0969)
1997-2006	Obs	1285	1262	1285	1262	1285	1262	1285	1262
	R^2	0.270	0.284						
	Connect	-0.0497*	-0.0914***	-0.0542	-0.223*	-0.175	-0.315**	-0.0926	-0.257***
Change ln(GovRevenue)		(0.0285)	(0.0295)	(0.109)	(0.120)	(0.117)	(0.132)	(0.0893)	(0.0996)
1997-2006	Obs	1290	1285	1290	1285	1290	1285	1290	1285
	R^2	0.275	0.334						
	Connect	-0.00204	-0.0144	-0.106	-0.177*	-0.178	-0.254**	-0.127	-0.203**
Change ln(GDP)		(0.0245)	(0.0276)	(0.0830)	(0.0942)	(0.112)	(0.116)	(0.0824)	(0.0886)
1997-2006	Obs	1297	1272	1297	1272	1297	1272	1297	1272
	R^2	0.228	0.264						
	Connect	-0.00344	-0.00790	0.000194	-0.0252	-0.0305	-0.0597	-0.00865	-0.0371
Change ln(AgGVA)		(0.0210)	(0.0220)	(0.0631)	(0.0789)	(0.0672)	(0.0728)	(0.0545)	(0.0630)
1997-2006	Obs	1335	1313	1335	1313	1335	1313	1335	1313
	R^2	0.202	0.208						
	Connect	0.00488	-0.00217	0.0395**	0.0264	0.0183	0.0104	0.0333*	0.0207
Change ln(Population)		(0.00456)	(0.00568)	(0.0188)	(0.0234)	(0.0242)	(0.0262)	(0.0183)	(0.0215)
1997-2006	Obs	1337	1314	1337	1314	1337	1314	1337	1314
	R^2	0.234	0.271						

All regressions include province fixed effects. LCP IV stands for the least cost path spanning tree instrument. Euclid IV stands for the straight line spanning tree instrument. "No controls" columns refer to regressions on NTHS treatment and log county distance to the nearest targeted city node. "With controls" indicates a full set of 1990 county controls (city status and prefecture capital dummies, log urban population, share of agricultural employment, and share of above compulsory school attainment in 20+ population). The dependent variables in order as listed are county level industry gross value added, manufacturing plus services gross value added, local government revenue, total GDP, agricultural gross value added, and population. Standard errors are clustered at the province level and stated in parentheses below point estimates. ***1%, **5%, and *10% significance levels.

Table 4: Placebo falsification test before and after the network was built

Dependent Variable: Change ln(LocGovRev)	(1) OLS 1990-97	(2) OLS 1997-06	(3) LCP IV 1990-97	(4) LCP IV 1997-06	(5) Euclid IV 1990-97	(6) Euclid IV 1997-06	(7) Both IVs 1990-97	(8) Both IVs 1997-06
Panel A: Binary								
Connect	0.0154	-0.0848**	0.0143	-0.151	0.117	-0.282**	0.0563	-0.204***
	(0.0410)	(0.0360)	(0.0853)	(0.0974)	(0.107)	(0.129)	(0.0647)	(0.0467)
Obs	894	894	894	894	894	894	894	894
R^2	0.274	0.339						
First stage F-Stat			19.635	19.635	19.091	19.091	14.930	14.930
Panel B: log Distance								
ln(DistHwy)	-0.0114	0.0160	-0.0409	0.0854*	-0.00442	0.185**	-0.0274	0.122***
	(0.0142)	(0.0190)	(0.0350)	(0.0470)	(0.0573)	(0.0783)	(0.0329)	(0.0430)
Obs	894	894	894	894	894	894	894	894
R^2	0.275	0.336						
First stage F-Stat			18.696	18.696	17.306	17.306	11.259	11.259

All regressions include province fixed effects. LCP IV stands for the least cost path spanning tree instrument. Euclid IV stands for the straight line spanning tree instrument. Regressions include the full set of controls. Panel A presents results for binary NTHS connection indicators, and Panel B presents results for log distance to the nearest NTHS segment. Standard errors are clustered at the province level and stated in parentheses below point estimates. ***1%, **5%, and *10% significance levels.

Table 5: Testing Propositions 4 and 5 on interaction effects of peripheral network connections

Dependent Variable:	Change ln(IndGVA) 1997-2006					Change ln(GDP) 1997-2006				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Panel A: Binary										
Connect	-0.304**	-4.281***	-4.236***	-3.147	-6.001**	-0.177*	-3.571***	-3.483***	-3.218**	-4.597**
	(0.145)	(1.569)	(1.620)	(2.146)	(2.575)	(0.0942)	(1.011)	(1.023)	(1.533)	(1.848)
Connect*ln(DistNode)		0.748***	0.740***	0.784***	0.891*		0.636***	0.626***	0.649***	0.759**
		(0.270)	(0.277)	(0.267)	(0.472)		(0.172)	(0.172)	(0.170)	(0.312)
Connect*Emp90Dum		0.450*	0.473*	0.468*	0.689		0.404**	0.485***	0.412**	0.642**
		(0.255)	(0.253)	(0.262)	(0.444)		(0.196)	(0.184)	(0.193)	(0.315)
Obs	1280	1280	1280	1280	1020	1272	1272	1272	1272	1024
First stage F-Stat	29.966	3.462	1.765	2.601	1.317	27.972	4.724	1.717	2.517	1.553
Panel B: log Distance										
lnDistHwy	0.0954	1.465***	1.495***	1.067	1.689***	0.0639	1.105***	1.109***	0.861*	1.238***
	(0.0674)	(0.455)	(0.463)	(0.669)	(0.562)	(0.0434)	(0.318)	(0.324)	(0.507)	(0.437)
lnDistHwy *ln(DistNode)		-0.236***	-0.239***	-0.245***	-0.239***		-0.181***	-0.181***	-0.180***	-0.184***
		(0.0748)	(0.0762)	(0.0737)	(0.0821)		(0.0494)	(0.0501)	(0.0502)	(0.0619)
lnDistHwy*Emp90Dum		-0.266***	-0.250***	-0.250***	-0.258**		-0.192***	-0.188***	-0.184***	-0.192**
		(0.0823)	(0.0823)	(0.0821)	(0.111)		(0.0693)	(0.0673)	(0.0675)	(0.0833)
Obs	1280	1280	1280	1280	1020	1272	1272	1272	1272	1024
First stage F-Stat	22.367	4.649	2.720	2.286	2.004	21.698	4.842	2.876	2.549	2.355

All regressions include province fixed effects. Reported results are two-stage least squares estimates using the least cost path spanning tree to instrument for NTHS treatments as well as their reported interaction terms. lnDistNode is log county distance to the nearest targeted city node. Emp90Dum is a dummy for counties with above mean levels of county employment in 1990. All regressions include a full set of county controls. Columns 1 and 2 do not include controls for additional interaction terms. Column 3 reports results after including additional interaction terms between NTHS treatments and a dummy indicator for city status in 1990, as well as a dummy indicator for prefecture level capital status in 1990. Column 4 reports results after including NTHS interactions with 1990 county shares of above compulsory schooling in 20+ population, as well as 1990 county shares of agricultural employment. Column 5 reports results after including an interaction term with log 1990 county government revenue per capita. Standard errors are clustered at the province level and stated in parentheses below point estimates. ***1%, **5%, and *10% significance levels.

Table 6: Best fitting parameter combinations

Rank	Distance Parameter (δ)	Elasticity of Substitution (σ)	Trade Cost Elasticity (Φ)	Simulated Average Treatment Effect	Sum of Squared Deviations from Two Estimated Interaction Terms
1	1.14	2.4	-1.60	-0.293***	0.156
2	1.04	2.6	-1.66	-0.301***	0.197
3	0.96	2.8	-1.73	-0.298***	0.223

The table presents three parameter combinations that yield statistically significant simulated average connection effects within +/-0.5 percentage points of the estimated instrumental variable coefficient in the final column of Table 3. In addition, the presented configurations yield statistically significant (10% level) cross-derivate effects with respect to county size and distance to the nearest targeted center in line with the effects estimated by two stage least squares in Table 5. The ranking refers to the sum of squared deviations over the two estimated interaction coefficients presented in Table 5. ***1%, **5%, and *10% significance levels.

Table 7: Simulation results for the all-China county sample

Dependent Variable: Simulated Change ln(IndOutput)	(1)	(2)
Peripheral Counties (Constant)	-0.313***	
	(0.0761)	
Targeted Metropolitan City Regions	0.319***	0.312***
	(0.0712)	(0.0873)
Province Fixed Effects	No	Yes
Obs	1679	1679
R^2	0.01	0.18

The table presents results from an OLS regression of simulated changes in log county industrial output on an identifier that takes the value of one for targeted metropolitan city regions, and zero otherwise. Simulated outcomes are based on the best fitting parameter configuration presented in Table 6. Column 2 includes province fixed effects. Standard errors are clustered at the province level and stated in parentheses below point estimates. ***1%, **5%, and *10% significance levels.

Table 8: Simulated changes to china's concentration of industrial activity

	All-China Counties	Within Peripheral County Group	Within Targeted City Region Group
Observed Herfindahl 1997	0.0129	0.0036	0.0381
Simulated Herfindahl After NTHS	0.0134	0.0039	0.0383
Percentage Change	3.9	8.3	0.5
Observations	1679	1625	54

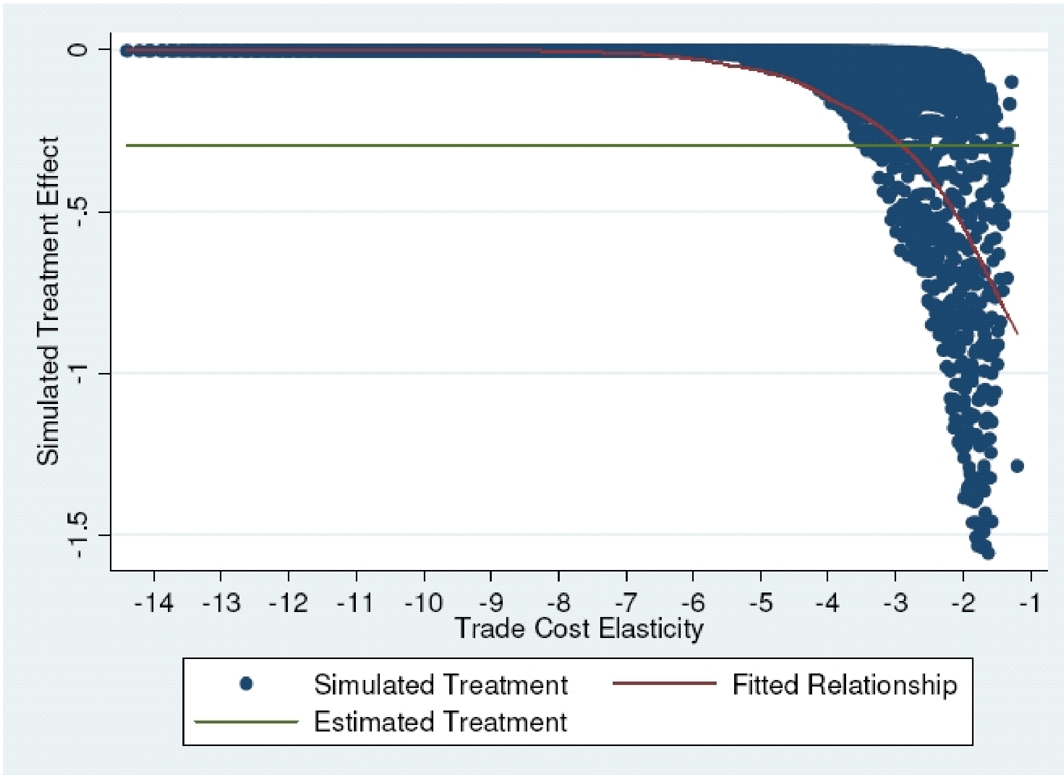
Table 9: Simulated effects on local price indices

Dependent Variable: Simulated Change ln(Price Index)	(1)	(2)	(3)	(4)
All-China Average	-0.0106***	-0.0107***		
	(0.000918)	(0.00103)		
Non-Connected Periphery (Constant)			-0.00242***	
			(0.000295)	
Connected Periphery			-0.0254***	-0.0258***
			(0.00260)	(0.00273)
Targeted Metropolitan City Regions			-0.00243***	-0.00410***
			(0.000528)	(0.000874)
Province fixed effects	No	No	No	Yes
1997 Population Weighted	No	Yes	No	No
Obs	1679	1671	1679	1679
R^2	0.000	0.000	0.208	0.234

The table presents results from OLS regressions of simulated changes in the log county ideal price index on a constant (in Columns1 and 2), and on two group identifiers as indicated in Columns 2 and 3 where non-connected peripheral counties constitute the third group in the reference category. Simulated outcomes are based on the best fitting parameter configuration presented in Table 6. Standard errors are clustered at the province level and stated in parentheses below point estimates. ***1%, **5%, and *10% significance levels.

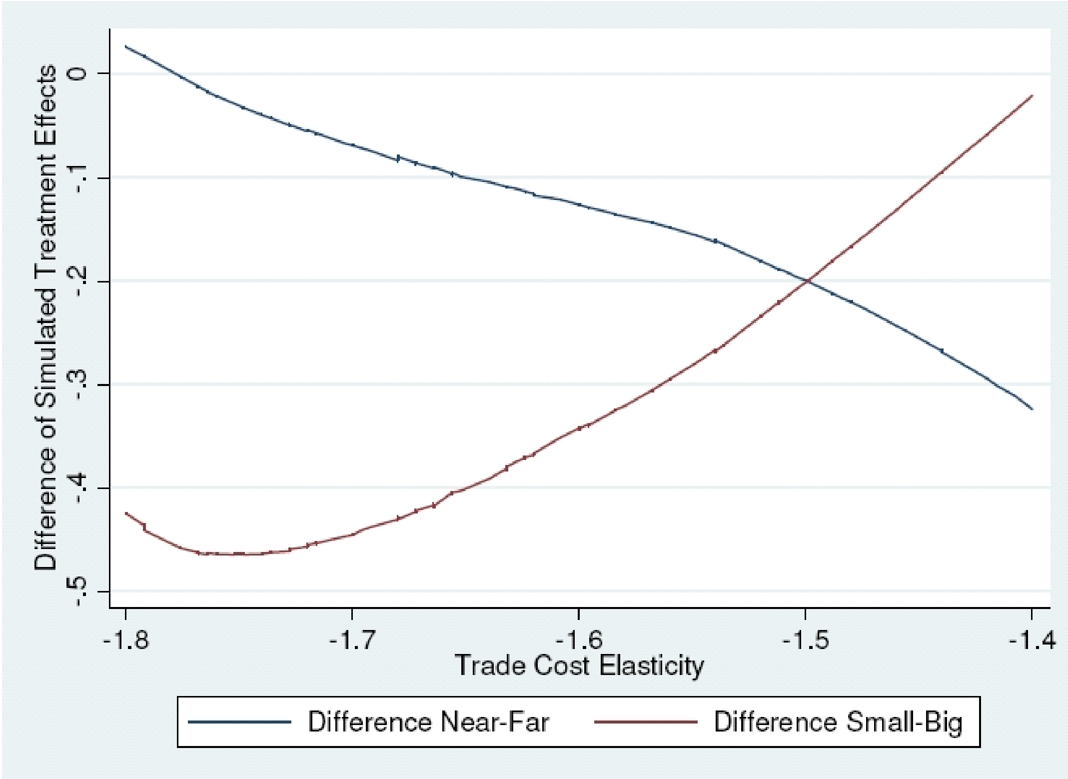
Appendix

Figure A.1: Simulated average treatment effects across the parameter space



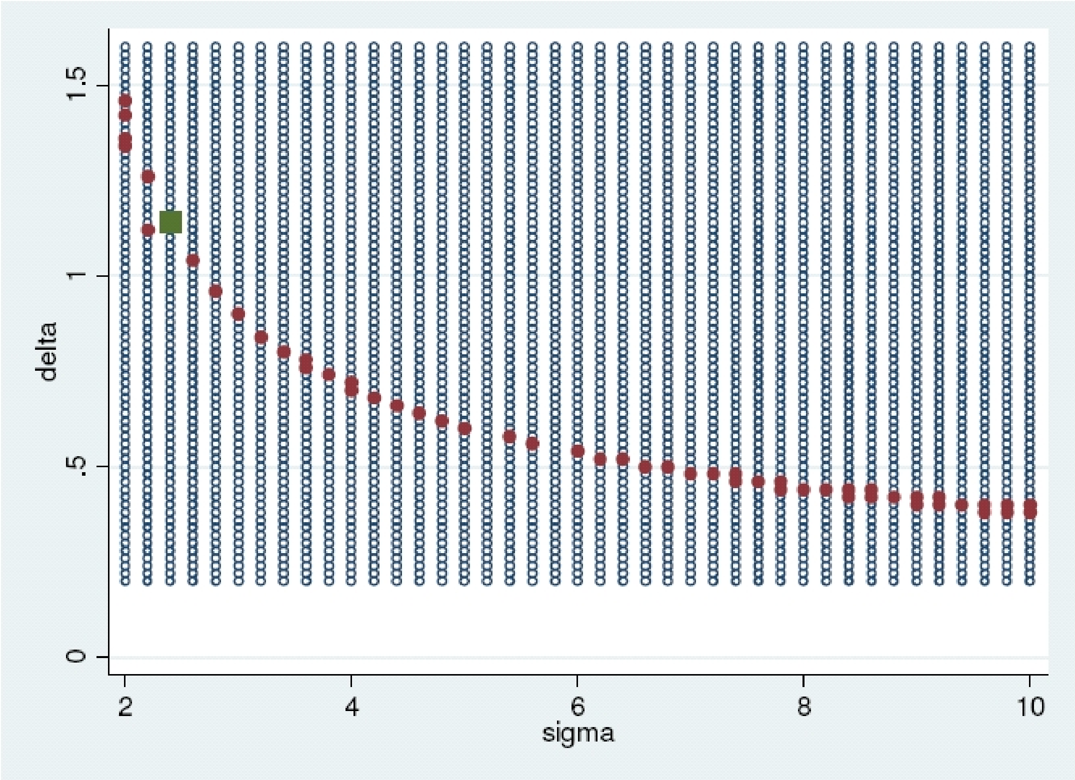
The y-axis displays regression coefficients of county level simulated industrial growth on binary NTHS connection treatments, province fixed effects, and a full set of 1990 county controls for the peripheral county sample. Each dot represents a separate vector of simulated county growth rates. The horizontal line indicates the estimated instrumental variable NTHS effect for the identical peripheral county sample and specification as presented in the final column of Table 3. Trade cost elasticity is the elasticity of trade flows to distance (δ*(1-σ)). Depicted results are based on the baseline estimate of NTHS transportation costs relative to existing roads as described in the text. The graph suppresses extreme simulation results at lower levels of trade costs at which a significant fraction of peripheral counties are at the corner solution with zero remaining industry. The fitted line refers to a locally weighted linear least squares regression (bandwidth 0.8).

Figure A.2: Simulated treatment effects for different county groups



The y-axis displays the difference of regression coefficients of simulated county industrial growth on binary NTHS connection treatments and province fixed effects between different groups of peripheral counties. Regression coefficients are estimated separately for sub-samples of above mean ("Far") and below mean distance ("Near") to the nearest targeted metropolitan region, as well as above mean ("Big") and below mean ("Small") 1990 total employment. The fitted lines refer to locally weighted linear least squares regressions (bandwidth 0.8). Trade cost elasticity refers to the elasticity of trade flows to distance (δ*(1-σ)).

Figure A.3: Parameter configurations within 10% of estimated average treatment effect



The graph depicts the parameter space where each circle represents one vector of simulated county outcomes subject to the baseline parameterization of NTHS transport costs relative to existing roads described in the text. The solid circles indicate parameter combinations of the distance parameter (δ) and the elasticity of substitution (σ) for which the simulated average treatment effect among peripheral counties is statistically significant at the 10% level and within three percentage points of the estimated 2nd stage IV estimate presented in the final column of Table 3 (within 10% of point estimate). The solid square indicates the best fitting parameter combination identified by the grid search and presented in Table 6.