Intercity Trade and Housing Prices in US Cities[1]

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Intercity Trade and Housing Prices in US Cities

Jeffrey P. Cohen and Yannis M. Ioannides

Abstract

Urban models often examine the consequences of domestic trade for city structure. We consider how GDP growth impacts Metropolitan Statistical Area (MSA) housing price growth, while allowing for iceberg shipping costs. We develop a theoretical model of spatial equilibrium among cities where there is capital mobility between them and explore its empirical predictions. Using instrumental variables (IV), and a unique set of instruments including time-varying MSA-level military contract awards, we identify city-level GDP growth impacts on city house price growth. This equation follows from imposing spatial equilibrium across cities. In general, our empirical estimation results confirm the signs of the relationships predicted by the theory, i.e., greater GDP growth in a city leads to higher house prices. Our theoretical approach, synthesis of MSA-level data, and empirical analysis are novel.

1 Introduction

Cities are vibrant hubs of economic activity and culture. They host a large and indeed ever increasing share of population. For a city to function its economy must provide non-tradeable goods and services, which are required for each city's survival. Cities also typically produce tradeable goods, which are exported to the rest of the economy, thus allowing their economies to import goods that are consumed by their population and industries. Urban economic activity provides employment and is accommodated by each city's real estate sector. Real estate encompasses housing and non-housing structures. Housing prices and rents are key determinants of the cost of urban production and urban living. Urban economies are profoundly open to domestic competition.

Research on housing markets and prices typically looks either at the housing market alone, or at the housing and labor markets jointly. Other research on international trade, such as Autor, Dorn, and Hanson (2013), considers the relationship between trade and the labor markets. Our research reported here is motivated by a literature that links local housing markets and trade. It innovates by bringing into the analysis some additional but lesser known sources of data, which are critical for understanding urban economies as open economies. One is the Bureau of Economic Analysis (BEA) data on MSA GDP, which starts in 2002 and is reported annually for 381 US MSAs.[4] A second source is little known data on federal military procurement contracts awarded to individual establishments, and the location of work performance. We roll up each establishments' zip codes to the MSA level in order to obtain an estimate of the value of MSA-level military contract work. We use the growth in these MSA-level military contracts, and the level of these military contracts, as instruments for GDP growth and GDP, respectively. While Nakamura and Steinsson (2014) use national-level and state-level military procurement data as an instrument, our development of an MSA-level approach for estimating military procurement values is completely novel.

Finally, we utilize the Donaldson and Hornbeck (2016) market access approach to develop

[4]http://www.bea.gov/newsreleases/regional/gdp_metro/gdp_metro_newsrelease.htm

estimates of city-level goods prices that depend on distances between U.S. cities. Our empirical results confirm our theoretical model's prediction of a positive relationship between house price growth and GDP growth at the MSA level.

To the best of our knowledge, the paper's approach is innovative; we are unaware of any previous research that synthesizes the city-level housing price data with the Donaldson and Hornbeck market access approach, along with the unique city-level military contracts instrument that we have developed.

The remainder of this paper is organized as follows. We first develop a theoretical model of spatial equilibrium with multiple city types. This model predicts that there are structural differences across cities of different types in the determination of how GDP growth affects the growth of city-level house prices. The empirical implications of spatial equilibrium have been tested before when analyzing interactions among US cities [c.f. Glaeser *et al.* (2014)], yet the possibility of structural differences across US cities has not been analyzed. In this regard, we then describe the data and discuss our empirical results. We conclude with some overall discussion and suggestions for future research.

2 Literature Review

There is relatively little literature that emphasizes empirically the structural implication of intercity trade, city output, and house price growth. Much of it pertains to either city trade or house prices, but less focus has centered on both together with gross domestic product.

Several applications have been published of approaches to estimate the external shocks to a city's economy, which is traced back to an exports price index first developed by Pennington-Cross (1997). But much of the related literature pertains to international trade rather than intercity trade. Other subsequent applications include Hollar (2011), which is a study on central cities and suburbs; Larson (2013), which considers housing and labor markets in growing versus declining cities; and Carruthers *et al.* (2006) on convergence. Most of these papers use a similar earlier data set on exports from the 1990s from the International

Trade Agency (ITA), which was discontinued prior to 2000. [5]

A second but smaller strand of literature uses actual export quantities as control variables, with the exports data being the central focus of the paper for only some of these industries. For others they are not the primary focus of the papers (they are merely used as controls). These include Lewandowski (1998), which considers economies of scale of exports in MSAs. [6] Ferris and Riker (2015) study the relationships between exports and wages, using a more recent data set on exports, but focus on measurement and data construction aspects. Braymen *et al.* (2011) examine R&D and exports, using a somewhat limited, firm level database on exports from the Kauffman Foundation, and control for R&D activity in the metro area. Vachon and Wallace (2013) use the exports data to assess how globalization affects unionization in 191 MSAs.

A more recent paper by Li (2017) uses a rudimentary empirical analysis to motivate a theoretical model and simulations for US cities that describes the relationship between house prices and comparative advantage. The theory is the primary focus of that paper. Our understanding of export-oriented cities would benefit from further analytical and empirical attention, together with fewer limitations of some of the other exports data sources. This is in view of the sparseness of published research integrating theoretical underpinnings with rigorous empirical modelling on house prices, GDP, and mobility of goods and residents at the MSA level.

Rosen (1979) and Roback (1982) develop models that have been more recently used to describe spatial equilibrium in housing markets, as in Glaeser *et al.* (2014). The spatial equilibrium approach typically assumes perfect labor mobility and fixed land. Spatial equilibrium within each city implies that land rent is function of distance to the city center, and transport costs within the city.[7]

[5] A new exports data set has been released by the ITA beginning in 2005, although one drawback of that data source is that it is based on origin of shipments rather than origin of production.

[6] Lewandowski (1998) uses the earlier exports data set from the ITA.

[7] The spatial equilibrium condition, which expresses arbitrage, turns out to have major implications for urban growth equations in the context of economic integration. These consequences have been emphasized recently by Hsieh and Moretti (2017). They show empirically that spatial equilibrium introduces dependence among city growth rates, which makes the contribution of a particular city to aggregate growth differ significantly from what one might naively infer from the growth of the city's GDP by means of a standard

In the real world, cities are not autarkic and typically interact with others. Desmet and Rossi-Hansberg (2015), and Ioannides (2013) develop standard approaches for modeling interactions among systems of cities, relying on the notion of spatial equilibrium.[8] Duranton and Puga (2014) offer a comprehensive treatment of growth in a system of cities that also links theoretical predictions with empirical specifications.

In spatial equilibrium models, estimating intercity shipping costs has become an issue of focus. The Donaldson and Hornbeck (2016) pioneering work in this area uses intercity distances to proxy for shipping costs. There has been a large growth in research in this area subsequently, including Jedwab and Storeygard (2020) among others.

Recent attention has focused on the context of housing and market access. The concept of access to highway and/or road infrastructure has been explored in a number of studies after Donaldson and Hornbeck (2016). In this large follow-up literature on access, highway access for a given residential property is defined as the drive time from that property to the nearest highway exit, with the implication that the highway provides access to various employment and goods markets. In the European context, Hoogendoorn*et al.* (2019) consider a new highway tunnel that was opened in 2003 in the Netherlands, and how access by road associated with the tunnel impacted house prices. They consider housing accessibility

growth-accounting exercise. They show that the divergence can be dramatic. E.g., despite some of the strongest rate of local growth, New York, San Francisco and San Jose were only responsible for a small fraction of U.S. growth during the study period. By contrast, almost half of aggregate US growth was driven by growth of cities in the South. This divergence is due to the fact that spatial equilibrium imposes restrictions on city-specific TFP growth rates. Future work might condsider both international and intercity trade in the Hsieh and Moretti (2017) context.

[8] In a related literature originating with Henderson (1974), city types differ according to the number and types of final goods produced, or whether or not they produce only intermediate goods and import all final goods. Ioannides (2013), Chapter 7, develops a variety of rich urban structures in a static context and *ibid.,* Chapter 9, in a dynamic one. Both approaches impose intracity and intercity spatial equilibrium. In the case of the static model, manufactured goods may be either produced locally or imported from other cities. Manufactured goods are produced using raw labor and intermediate goods interpreted as specialized labor, which are themselves produced from raw labor, using increasing returns to scale (IRS) technologies. In the case of the dynamic model, manufactured goods are produced using raw labor and intermediate goods interpreted as specialized labor, which are themselves produced from raw labor, using IRS technologies, and physical capital. In either case, those goods are combined locally to produce a final good that may be used for either consumption or investment. Urban functional specialization, rather than sectoral, as articulated by Duranton and Puga (2005), also leads to structural differences. In other words, certain economic functions, like management, research and development and corporate headquarters may be located in different places than manufacturing. With industrial specialization and diversification being important features of urbanized economies, cyclical patterns in urban output differ across cities, and so do patterns in the variations of employment and unemployment [Rappaport (2012); Proulx (2013)].

to a highway improvement in terms of travel time savings, along with a variety of distance decay functions, and find an access elasticity of 0.8. Their access index definition is based on a function of travel time by car to a particular destination and the number of employment opportunities available at that destination. House prices are significantly impacted by better access. Using a difference-in-differences estimation approach, Levkovich*et al.* (2016) study the house price impacts of new highways in the Netherlands. Levkovich*et al.* (2016) also develop an access index, based on the population density at various locations, and find that the elasticity of house prices with respect to access is roughly 1.76. In other words, improved market access has a greater than proportional increase in house prices.

While these two house price studies (which are based on hedonic modelling) focus on market access at a more micro level, similar attention can be centered around MSA-level market access measures and how they might relate to city-wide housing price growth. In our context, we use the inverse distance function between MSA pairs (also known as iceberg shipping costs), along with level of employment and output in cities, to estimate a goods price index as in Donaldson and Hornbeck (2016). We then use this goods price index in implementation of our empirical tests of our spatial equilibrium theory that considers how MSA-level house price growth depends on other MSA-level structural factors.

In light of our goal of examining the determinants of MSA-level house price growth, another challenge is identifying the causal relationships between house price growth and GDP growth at the city level. We propose a novel instrument, which is the growth rate of MSA-level military contracts. The idea of military growth contracts as an instrument has been used in other contexts, such as Nakamura and Steinsson (2014), although their approach is to use more readily-available state-level or national-level military contracts data. They note that others have argued national-level military expenditure is exogenous to the business cycle and state-level expenditures are similarly exogenous to state-level output because the military does not engage in a build-up in response to states' business cycle conditions. We further build upon the Nakamura and Steinsson (2014) approach with our method of rolling up project-level data using zip code data of the establishments to which these federal awards were granted. Specifically, Nakamura and Steinsson (2014) interact national-level procurement data with state-level dummies as one approach to instrumentation for national-level GDP; and a second IV approach following the general idea of Bartik (1991), with which Nakamura and Steinsson (2014) scale national spending for each state by the ratio of state-level military spending at a point in time to the state's average output in the first 5 years of their sample. Our problem is more complex with several endogenous variables and multiple instruments, but our MSA-level estimates of military expenditures allow for a MSA-level GDP instrument that has not (to our knowledge) been previously explored.

3 Intercity Trade and the Housing Market

Drawing on standard approaches for modeling interactions among systems of cities [Desmet and Rossi-Hansberg (2015); Ioannides (2013)], the present paper describes an economy as being made up of cities of different types. Types differ according to the number and types of final goods produced, or whether or not they produce only intermediate goods and import all final goods. This literature originated by Henderson (1974). The present paper draws from Ioannides (2013), Chapter 7, which develops a variety of rich urban structures in a static context and *ibid.,* Chapter 9, in a dynamic one. Both approaches impose intracity and intercity spatial equilibrium. In the case of the static model, manufactured goods may be either produced locally or imported from other cities. Manufactured goods are produced using raw labor and intermediate goods interpreted as specialized labor, which are themselves produced from raw labor, using increasing returns to scale (IRS) technologies. In the case of the dynamic model, manufactured goods are produced using raw labor and intermediate goods interpreted as specialized labor, which are themselves produced from raw labor, using IRS technologies, and physical capital. In either case, those goods are combined locally to produce a final good that may be used for either consumption or investment. Urban functional specialization, rather than sectoral, as articulated by Duranton and Puga (2005), also leads to structural differences. In other words, certain economic functions, like management, research and development and corporate headquarters may be located in different places than manufacturing. With industrial specialization and diversification being important features of urbanized economies, cyclical patterns in urban output differ across cities, and so do patterns in the variations of employment and unemployment [Rappaport (2012); Proulx (2013)].

3.1 A Model of Urban Economic Integration and Specialization

The exposition that follows extends the main model in Ioannides (2013), Chapter 9, in order to allow for housing.[9] It is a dynamic model that allows for differences across cities of local congestion parameters κ_i. It assumes that individuals are free to move within and across cities, that is, spatial equilibrium is imposed in terms of individuals' lifetime utilities. This implies in turn conditions on intercity housing price and income growth patterns. The paper also assumes perfect capital mobility, which implies that nominal returns are equalized across all cities. Indeed, this assumption has a major implication, namely that the growth process in all cities depend on national physical capital accumulation.

This section aims at obtaining a more general expression for spatial equilibrium and its implications for the growth rate of the price of housing (that is of land, in our case).[10]

A number of individuals $\bar{N}_t$ are born every period and live for two periods. The economy has the demographic structure of the overlapping generations model, the workhorse of modern macroeconomics. We assume that individuals born at time t work when young, consume nonhousing and rental housing out of their their labor income net of their savings, (C_{1t}, G_{1t}), and consume again when they are old, $(C_{2t+1}, G_{2,t+1})$ respectively, out of their total resources. They leave no bequests. We assume Cobb-Douglas preferences over first- and second-period consumption for the typical individual,

$$U_t = S^*[C_{1t}^{1-\beta} G_{1t}^{\beta}]^{1-S}[C_{2t+1}^{1-\beta} G_{2,t+1}^{\beta}]^S, \ 0 < S < 1, \tag{1}$$

where $S^* \equiv [S^{1-\beta}\beta^{\beta}]^{-S}[(1-S)^{1-\beta}\beta^{\beta}]^{-(1-S)}$, and parameter S satisfies $0 < S < 1$. Note that

[9] This main model of Ioannides, Ch. 9, constitutes an original adaptation of Ventura (2005)'s model of global growth to the urban structure of a national economy by building on key features of Ioannides (2013), Ch. 7.

[10] An extension of the model for the case of international trade is pursued in an appendix.

this formulation subsumes time preference, as it is not critical for our analysis.[11]

Labor, net of commuting time, supplied by the young generation in a particular city at t is given by

$$H_t = N_t \left(1 - \kappa N_t^{\frac{1}{2}}\right),$$

with N_t the number of the members of the young generation at t, $\kappa_i \equiv \frac{2}{3}\pi^{-\frac{1}{2}}\kappa_i'$, and κ' the time cost per unit of distance traveled. Let W_t denote the wage rate per unit of time. Spatial equilibrium within the city obtains when labor income net of land rent is independent of location. This along with the assumption that the opportunity cost of land is 0, and therefore the land rent at the fringe of the city is also equal to 0, yields an equilibrium land rental function; see Chapter 7, Ioannides (2013). It declines linearly as a function of distance from the CBD and is proportional to the contemporaneous wage rate, W_t. It is convenient to close the model of a single city and to express all magnitudes in terms of city population, N_t, to be referred to as size, too. We again assume that all land rents in a given city are redistributed to its residents when they are young, in which case total rental income may be written in terms of the number of young residents as $\frac{1}{2}\kappa W N_t^{\frac{3}{2}}$. This yields first period net labor income per young resident, after redistributed land rentals are added and net of individual commuting costs, of $\left(1 - \kappa_i N_t^{\frac{1}{2}}\right) W_t$. With a given wage rate, individual income declines with city size, entirely because of congestion. But, there are benefits to urban production which are reflected on the wage rate.

Let R_{t+1} be the economy-wide nominal return to physical capital, K_{t+1}, in time period $t+1$, that is held by a member of young generation at time t. Let $P_{i,t}, P_{i,G,t}$ denote the price of consumption and the (rental) price of housing in city i at time t. The indirect utility function corresponding to (1) is:

$$V_{i,t} = R_{t+1}^{S(1-\beta)} P_{i,t}^{-(1-S)(1-\beta)} P_{i,G,t}^{-(1-S)\beta} P_{i,t+1}^{-(1-S)(1-\beta)} P_{i,G,t+1}^{-S\beta} \left(1 - \kappa N_t^{\frac{1}{2}}\right) W_t. \tag{2}$$

We assume that capital depreciates fully in one period. The young maximize utility by

[11] An additively separable version of (1) readily follows by taking logs. However, it is equivalent to the levels-version. Furthermore, uncertainty could be dealt with by taking logs.

saving a fraction S of their net labor income. The productive capital stock in period $t+1$, K_{t+1}, is equal to the total savings of the young at time t. Therefore, previewing our growth models, we have: $K_{t+1} = SN_t \left(1 - \kappa N_t^{\frac{1}{2}}\right) W_t$.

We refer to the case where capital and labor are free to move as *economic integration.* With economic integration, industries will locate where industry productivities, the industry-specific TFP functions Ξ_{Jt}'s,[12] are the most advantageous, and capital will seek to locate so as to maximize its return. Unlike the consequences of economic integration as examined by Ventura, *op. cit.,* where aggregate productivity is equal to the most favorable possible in the economy, here urban congestion may prevent industry from locating so as to take greatest advantage of locational factors alone. Put differently, free entry of cities into the most advantageous locations may be impeded by competing uses of land as alternative urban sites, at the national level. However, utilities enjoyed by city residents at equilibrium do depend on city populations, and therefore, spatial equilibrium implies restrictions on the location of individuals. We simplify the exposition by assuming that all cities have equal unit commuting costs κ.

We assume that cities specialize in the production of tradeable goods. We examine the case when each specialized city also produces intermediates that are used in the production of the traded good. Let Q_{Xit}, Q_{Yjt} denote the total quantities of the traded goods X, Y produced by cities i, j, that specialize in their production, respectively. The formulation is symmetrical for the two city types, and therefore, we work with a city of type X.

The canonical model of an urban economy assumes that capital is free to move. Thus, nominal returns to capital are equalized across all cities. The model assumes that young individuals are free to move, which in the context of our two-overlapping generations requires that lifetime utility is equalized across all cities. By using these conditions simultaneously, we obtain a relationship between housing prices, consumption good prices and nominal incomes across cities, which may be taken to the data.

[12] See Appendix A for details on the specification of the urban production structure and clarification of the role of the industry-specific TFP functions Ξ_{Jt}'s.

3.1.1 Spatial Equilibrium

We suppress redundant subscripts and write for the nominal wage and the nominal gross rate of return in an type$-X$ city:

$$W_{Xt} = (1-\phi_X)\frac{P_X Q_X}{H_X},\ R_{Xt} = \phi_X \frac{P_X Q_X}{K_X}, \tag{3}$$

where P_X denotes the local price of traded good X, which is expressed in terms of the local price index, the numeraire, which is equal to one in all cities. We also assume initially that there are no intercity shipping costs for traded goods. With economic integration, the gross nominal rate of return is equalized[13] across all city types, that is:

$$R_t = R_{Xt} = R_{Yt}.$$

Spatial equilibrium for individuals requires that indirect utility, (2), be equalized across all cities. In view of free capital mobility, spatial equilibrium across cities of different types requires that:

$$\begin{aligned} &P_{X,t}^{-(1-S)(1-\beta)} P_{X,G,t}^{-(1-S)\beta} P_{X,t+1}^{-S(1-\beta)} P_{X,G,t+1}^{-S\beta}\left(1-\kappa N_{Xt}^{\frac{1}{2}}\right) W_{Xt} \\ &= P_{Y,t}^{-(1-S)(1-\beta)} P_{Y,G,t}^{-(1-S)\beta} P_{Y,t+1}^{-S(1-\beta)} P_{Y,G,t+1}^{-S\beta}\left(1-\kappa N_{Yt}^{\frac{1}{2}}\right) W_{Yt} \end{aligned} \tag{4}$$

By taking logs we have:

$$\begin{aligned} &-(1-S)(1-\beta)\ln P_{X,t} - (1-S)\beta \ln P_{X,G,t} - S(1-\beta)\ln P_{X,t+1} - S\beta \ln P_{X,G,t+1} + \ln\left(1-\kappa_X N_{Xt}^{\frac{1}{2}}\right) + \ln W_{Xt} \\ &= -(1-S)(1-\beta)\ln P_{Y,t} - (1-S)\beta \ln P_{Y,G,t} - S(1-\beta)\ln P_{Y,t+1} - S\beta \ln P_{Y,G,t+1} + \ln\left(1-\kappa_Y N_{Yt}^{\frac{1}{2}}\right) + \ln W_{Yt}. \end{aligned} \tag{5}$$

By rearranging this equation we obtain a condition for spatial equilibrium for each city, relative to cities of other types. Without loss of generality, we refer to the other city generi-

[13] As Fujita and Thisse (2009), p. 113, emphasize, while the mobility of capital is driven by differences in nominal returns, workers move when there is a positive difference in utility (real wages). In other words, differences in living costs matter to workers but not to owners of capital.

cally as the average city, n. In other words, spatial equilibrium is expressed for city i, relative to the urban economy:

$$GR_{t+1,t}(P_{i,G})-GR_{t+1,t}(P_{G,\mathrm{n}}) = -\frac{1-\beta}{\beta}\left[GR_{t+1,t}(P_i)-GR_{t+1,t}(P_{\mathrm{u}})\right]+\frac{1}{S\beta}\left[GR_{t+1,t}\Upsilon_j-GR_{t+1,t}(\Upsilon_{\mathrm{n}})\right]$$

$$-\frac{1}{S}\ln\left[\frac{P_{i,G,t}}{P_{n,G,t}}\right]-\frac{1-\beta}{S\beta}\ln\left[\frac{P_{i,t}}{P_{n,t}}\right]-\left[\ln\left(1-\kappa_X N_{i,t}^{\frac{1}{2}}\right)-\ln\left(1-\kappa_{\mathrm{n}} N_{\mathrm{n},t}^{\frac{1}{2}}\right)\right], \qquad (6)$$

where Υ_j is income (or GDP) per capita in city j and Υ_{n} is national income per capita. Clearly, broadly similar empirical models, obtained from a simpler behavioral models, may be nested within (6). In particular, the coefficient of $GR_{t+1,t}(P_j)-GR_{t+1,t}(P_{\mathrm{j,u}})$, the growth rate of the city price index relative to a national average, is predicted to be positive; the coefficient of $GR_{t+1,t}\Upsilon_j - GR_{t+1,t}(\Upsilon_{\mathrm{n}})$, the growth rate of income per capita relative to a national average, is predicted to be positive.

We impose a simplifying assumption on the exponents S and β in the utility function in (1) above. Recall that S is share of lifetime income spent on all consumption when old, and β is share of income in a given time period spent on housing relative to consumption of other goods. We assume they are equal.[14] This simplifies our (6) dramatically as follows:

$$GR_{t+1,t}(P_{i,G})-GR_{t+1,t}(P_{G,\mathrm{n}}) =$$

$$\frac{1}{\beta}\left[\ln\left[\frac{P_{i,t}}{P_{n,t}}\right]-\left[GR_{t+1,t}(P_i)-GR_{t+1,t}(P_{\mathrm{u}})\right]-\ln\left[\frac{P_{i,G,t}}{P_{n,G,t}}\right]\right]+$$

$$\frac{1}{\beta^2}\left[\left[GR_{t+1,t}\Upsilon_j-GR_{t+1,t}(\Upsilon_{\mathrm{n}})\right]-\ln\left[\frac{P_{i,t}}{P_{n,t}}\right]\right]+$$

$$\left[GR_{t+1,t}(P_i)-GR_{t+1,t}(P_{\mathrm{u}})\right]+\left[\ln\left(1-\kappa_X N_{i,t}^{\frac{1}{2}}\right)-\ln\left(1-\kappa_{\mathrm{n}} N_{\mathrm{n},t}^{\frac{1}{2}}\right)\right]. \qquad (7)$$

Since the theory implies the coefficient equals 1 on the third term in equation (7), and therefore it does not involve any parameter to be estimated, we rewrite (7) as follows:

$$GR_{t+1,t}(P_{i,G})-GR_{t+1,t}(P_{G,\mathrm{n}})-\left[GR_{t+1,t}(P_i)-GR_{t+1,t}(P_{\mathrm{u}})\right]=$$

[14]This assumption is reasonable given that they are both likely around 0.3 in the U.S.

$$\frac{1}{\beta}\left[\ln\left[\frac{P_{i,t}}{P_{n,t}}\right]-\left[GR_{t+1,t}(P_i)-GR_{t+1,t}(P_{\mathrm{u}})\right]-\ln\left[\frac{P_{i,G,t}}{P_{n,G,t}}\right]\right]$$
$$+\frac{1}{\beta^2}\left[\left[GR_{t+1,t}\Upsilon_j-GR_{t+1,t}(\Upsilon_{\mathrm{n}})\right]-\ln\left[\frac{P_{i,t}}{P_{n,t}}\right]\right]$$
$$+\left[\ln\left(1-\kappa_X N_{i,t}^{\frac{1}{2}}\right)-\ln\left(1-\kappa_{\mathrm{n}} N_{\mathrm{n},t}^{\frac{1}{2}}\right)\right]. \quad (8)$$

The last term in brackets in the right hand side above proxies for spatial complexity, regulation, and housing supply factors. It may be approximated as:

$$\kappa_X \ln\left[N_{i,t}^{\frac{1}{2}}\right]-\kappa_{\mathrm{n}}\ln\left[N_{\mathrm{n},t}^{\frac{1}{2}}\right].$$

Our final estimation equation is given by Eq. (8) above. We anticipate the coefficients to be positive on the first two terms on the right side of this equation. Clearly, GDP growth, the ratio of house prices in levels, and the ratio of goods prices in levels, all are anticipated to be endogenous. We discuss our IV approach in the data section below.

Next we account for the fact that the price index of aggregate consumption, $P_{i,t}$ in each city reflects the prices of goods imported from other cities. Under the assumption that all goods consumed are sourced from the lowest cost producer, a standard treatment in the new economic geography literature suggests a simplified way to account for market access. In view of the arguments and approximations in Donaldson and Hornbeck (2016), we use Eq. (4), (8) and (12) in *ibid.* to eschew a detailed derivation and use as the price index in city i the following expression:

$$P_{i,t}=\left[CMA_{i,t}\right]^{-\frac{1}{\theta}}=\left[\sum_o \tau_{oi}^{-\theta}(MA_{o,t})^{-1}\Upsilon_{o,t}\right]^{-\frac{1}{\theta}}=\left[\sum_o \tau_{oi}^{-\theta}\left(\sum_k \tau_{ok}^{-\theta}N_{k,t}\right)^{-1}\Upsilon_{o,t}\right]^{-\frac{1}{\theta}}, \quad (9)$$

where $MA_{o,t}$ denotes city o's market access, $MA_{o,t}=\sum_k \tau_{ok}^{-\theta}N_{k,t}$ (which involves that city's cost of trading with every other city k), N_k denotes employment in city $k, k\neq i$, Υ_o income per person (i.e., GDP) in city $o, o\neq i$, and τ_{oi},τ_{ok}, (iceberg) shipping costs. We follow Donaldson and Hornbeck (2016) and use intercity distances to proxy for shipping costs. However, they are raised to the power of $-\theta$, where θ denotes the trade elasticity, for which estimates in Donaldson and Hornbeck (2016) vary from 3.00 to 8.22 (where 8.22 is the Donaldson and Hornbeck estimate).

We apply this expression from our Eq. (9) in Eq. (8) above. Intuitively, what the market access formulation introduces is the spatial complexity of the entire urban economy, as distinct from the local spatial complexity as expressed by the last term in Eq. (8) above. The price index in each city $P_{i,t}$ is increasing in all (weighted) distances and employment elsewhere and decreasing in income elsewhere.

4 Overview of Data

We have assembled data from a variety of sources, which we use as comprehensively as possible to investigate the relationship between GDP, intercity trade, and the local housing markets. We describe these data to provide an overall view of the empirical resources we bring to our approach.

4.1 Data Sources

In this section we describe the major sources of data available to us, which we merge and append into one large dataset that we use for the estimation of Eq. (8). The combining of MSA data from these sources lead us to an unbalanced panel dataset, comprised of 197 MSAs, annually for the period 2003-2017. Since the dataset is unbalanced, we end up with 2,587 observations. One important note is that since we combine MSA-level data from many different sources, several of which use their unique definitions of the cities included in the respective MSAs, it is not always possible for us to merge data from all sources for all MSAs. This is particularly problematic for the largest MSAs that include many surrounding cities/suburbs. Due to these difficulties related to data merging, we drop some of the largest MSAs from our sample (such as New York City, Boston, Los Angeles, and Chicago). Therefore, our analysis primarily focuses on mid-sized and small MSAs.

Specifically, we draw our data for the primary variables in Eq. (8) from the following sources:

- House Price Index, $(P_{i,G})$: The Freddie Mac HPI data for each MSA is used as our house price index measure. In Table2 1 and 2 below, "hpi_gr" stands for the growth rate of the House Price Index, $GR_{t+1,t}(P_{i,G})$, for a given MSA i at a point in time, t.

- Payroll Employment, $N_{i,t}$: We use annual payroll employment data, as reported by the Bureau of Labor Statistics, for each MSA. We also construct an average employment variable for all MSAs. In the tables below, employ stands for the MSA employment level at a given year; "employ_term" stands for

$$\ln\left[N_{i,t}^{\frac{1}{2}}\right],$$

  and "employ_avg_term" stands for

$$\ln\left[N_{\mathrm{n},t}^{\frac{1}{2}}\right].$$

- Gross Domestic Product per capita in city j, Υ_j: Annual (nominal) GDP for MSAs, obtained from the BEA, in millions of \$.[15] In Tables 1 and 2 below, "gdp_gr" stands for $GR_{t+1,t}\Upsilon_j$.

- Goods Prices (P_i) : We use eq. (9) to calculate proxies for the goods prices, (P_i), where τ_{oi}, τ_{ok}, are as described above; N_k denotes employment in city $k; \Upsilon_o$ is GDP per person in city o; and θ denotes the trade elasticity parameter, for which estimates in Donaldson and Hornbeck (2016) vary from 3.00 to 8.22. In our analysis, we vary θ from 2.00 to 9.00, in increments of 0.50. The results we present below are for θ values of 7.00 and 9.00 (although a more comprehensive set of results are available upon request). Using distances (i.e., iceberg shipping costs) as a proxy for determining prices to some extent alleviates concerns regarding the potential endogeneity of goods prices; other instruments (i.e., those based on cancer death growth rates) are used to

[15]Missing MSAs were included manually from https://apps.bea.gov/iTable/index_regional.cfm

address the fact that our formulation of goods prices growth may be endogenous due to its dependence on GDP.

- Distances between MSAs: Latitude and Longitude of each MSA's centroid are calculated using ArcGIS, then these coordinates are used to calculate the Euclidean distances between MSAs. These distances are used in eq. (9) for calculating τ_{oi}, τ_{ok}, which are the (iceberg) shipping costs, where τ_{oi} is the Euclidean distance between the centroid of MSA o and centroid of MSA i (and similarly, τ_{ok} is the Euclidean distance between the centroid of MSA o and centroid of MSA k).

- Regressor 1: In Tables 3, 4, 5 and 6 Regressor 1 stands for:

$$\left[\ln\left[\frac{P_{i,t}}{P_{n,t}}\right] - [GR_{t+1,t}(P_i) - GR_{t+1,t}(P\mathrm{u})] - \ln\left[\frac{P_{i,G,t}}{P_{n,G,t}}\right]\right]$$

- Regressor 2: In Tables 3, 4, 5 and 6, Regressor 2 stands for:

$$\left[[GR_{t+1,t}\Upsilon_j - GR_{t+1,t}(\Upsilon\mathrm{n})] - \ln\left[\frac{P_{i,t}}{P_{n,t}}\right]\right]$$

Data for our instruments are as follows:

- Military Contracts Awarded: As described in the literature review section above, others, including Nakamura and Steinsson (2014), have used state-level military contracts data as an instrument for GDP. Their identifying assumption relies on the fact that the U.S. does not embark on a military build-up because states that receive a disproportionate amount of military spending are doing poorly relative to other states." Our approach is a significant innovation in that we have obtained data on the exact locations (including zip codes) of the contracting entities for all awarded military contracts, from the years 2003-2017,

  obtained from the Federal Procurement Data System. [16] We aggregate the individual

[16](https://www.fpds.gov/fpdsng_cms/index.php/en/, accessed in January 2020). Note that some entries are negative because the contract awards include funds that were returned to the federal government for non-performance or other reasons, therefore there is substantial variation in our MSA-level estimates.

contract award amounts by zip codes in each year, and then roll up the zip code level data to the MSA level. This leads us to an estimate of the value of military contracts awarded by MSA in each year. We rely on an argument similar to that of Nakamura and Steinsson (2014), since the military does not choose to engage in build-ups because of some MSAs doing "worse" or "better" than others in terms of their economic activities (MSA-level GDP).

- Completed Highway Miles: We use the number of completed highway miles per million population, at the MSA level, from Baum-Snow (2007).[17] We use the leccnp variable for 1993, as a proxy for highway miles in all years of our sample. Cities that ship more goods domestically are expected to rely heavily on the highway network (see, for example, Duranton et al., 2014), which was developed many years ago. For this reason, the size of the highway network (per person) in a particular city is used as an instrument for that city's GDP per capita; [18] a larger network in the city should lead to higher GDP. This variable also represents the congestion and/or roads quality within each city. This instrument is expected to be uncorrelated with shocks to city-level GDP because they pertain to past plans for highway rays and past completed highway miles that were in the original plan (from 1947). Shocks to GDP around 60 years later should be uncorrelated with the original plans and previous highway completions that were in the original plans. Our focus on highways that were in the original plan enables us to avoid the complications of new plans for highway construction, which more likely would be considered to be correlated with "shocks" to GDP. For instance, while a new decision to build another highway would be expected to be correlated with a city's domestic shipments, it also can be considered a shock to a city's current output if the new plan is unexpected. Therefore, focusing on highways that were in the original plan from the 1940's (as opposed to more recent plans) leads to a credible instrument for current domestic shipments.

[17] Details on how this variable is constructed can be found in Baum-Snow (2007), pages 802-803.

[18] While we use the estimate without year-to-year variation in the number of completed highway miles by MSA from Baum-Snow (2007), normalizing by population leads to annual variation and also offers a more precise instrument for the GDP measure that is in per-capita terms.

- Cancer Deaths: The difference between the MSA level cancer death growth rate and the national average cancer death growth rate is used as an instrument for:

$$[GR_{t+1,t}(P_i) - GR_{t+1,t}(P\mathrm{u})] .$$

Annual data on the cancer death rate for 96 MSAs comes from the U.S. Centers for Disease Control (CDC). For the remaining MSAs in our master dataset that do not have MSA-level death rates in the CDC database, we use the state-level death rate for the state in which the MSA is located. This cancer death rate is used in calculating the MSA level and national everage cancer death growth rates. In order to select this instrument, we recognize that economic activity in each city (GDP), and in turn, goods price levels based on our formulation of prices, is responsible for congestion, and air and water pollution, all of which have been shown to be correlated with (and in certain instances causal factors for) the incidence of cancer death rates internationally.[19] The complex dependence of income per person on city location serves to underscore the welfare costs of congestion.

- Unavailable Land Area: We utilize the Saiz (2010) data on MSA unavailable land area, and we normalize this by the MSA resident population (in millions) in each year (from the Census Bureau).

[19] See Coccia (2013) who relates breast cancer incidence to per capita GDP. The aim of this study is to analyze the relationship between the incidence of breast cancer and income per capita across countries. The numbers of computed tomography scanners and magnetic resonance imaging are used as a surrogate for technology and access to screening for cancer diagnosis. Coccia reports a strong positive association between breast cancer incidence and gross domestic product per capita, Pearson's r = 65.4 %, after controlling for latitude, density of computed tomography scanners and magnetic resonance imaging for countries in temperate zones. The estimated relationship suggests that 1 % higher gross domestic product per capita, within the temperate zones (latitudes), increases the expected age-standardized breast cancer incidence by about 35.6 % ($p < 0.001$). Clearly, wealthier nations may have a higher incidence of breast cancer even when controlling for geographic location and screening technology. Grant (2014) emphasizes that researchers generally agree that environmental factors such as smoking, alcohol consumption, poor diet, lack of physical activity, and others are important cancer risk factors for age-adjusted incidence rates for 21 cancers for 157 countries (87 with high-quality data) in 2008. Factors include dietary supply and other factors, per capita gross domestic product, life expectancy, lung cancer incidence rate (an index for smoking), and latitude (an index for solar ultraviolet-B doses). Per capita gross national product, in particular, was found to be correlated with five types, consumption of animal fat with two, and alcohol with one.

4.2 Descriptive Statistics

Tables 1 and 2 present descriptive stats for the data used for the period of 2003-2017 in the regression for Eq. (8) above. The first column of Table 1 reports the national averages for all MSAs. The average GDP growth rate was 3.6 percent, the average house price index growth rate was approximately 2 percent, and the average growth rate of cancer deaths was 0.21 percent. Military contracts grew at an average of 515 percent per annum; there are large fluctuations in the military contracts awarded and in some cases, when awarded funds are not expended in a given year, a portion of those funds are returned in a subsequent year (and counted as negative expenditures). This leads to a large amount of variation in the data. There were 39.2 planned highway miles per million population in the average MSA in our sample. The average number of payroll employment in all MSAs in all years was approximately 340,000 workers.

Tables 1 and 2 report descriptive statistics for 8 regions of the U.S. First, it is noteworthy that the Great Lakes region (column 4 of Table 1) is a source of outliers. That region had the greatest number of MSA-year observations, but its MSAs had the lowest average HPI growth (at 0.87 percent) among all 8 regions. The MSAs in the Great Lakes region also had the highest average cancer deaths growth rate among all regions, at 0.44 percent. The MSAs in the Great Lakes region also had the lowest average rate of growth of military contracts, at 335 percent. GDP growth in the Great Lakes region was only 2.87 for the average MSA, which is the lowest GDP growth rate average among all 8 regions.

New England MSAs experienced an average annual cancer death growth rate of -0.18 percent, which is the lowest (most negative) cancer death growth rate among all 8 regions. New England also had the greatest growth rate of military contracts among all 8 regions, at 729 percent. Finally, the average MSA in the Rocky Mountains had some of the most positive outliers among all 8 regions, with the highest GDP growth rate (4.64 percent for the average MSA), the highest HPI growth rate (3.46 percent), and more than 96 miles of planned highway miles per million population, which is more than double the next highest region (which is the Southwest, where the average MSA had roughly 47 miles per million population).

Finally, in most MSAs, the price index that we computed in eq. (9) is declining in most years. The price index is sensitive to the value of the parameter, θ. When θ is 9.00, the largest decline in the goods price index was for MSAs in the Rocky Mountains region, which saw an average of -0.50 percent change in their goods price index. On the other hand, the Great Lakes region MSAs saw the smallest decline in the goods price index (-0.29 percent). When we imposed θ to be 7.00, the average MSA goods price index growth in the Rocky Mountains declined by 0.64 percent, and the Great Lakes region average MSA saw an average goods price index decline of 0.37 percent. Given the variation in the goods price growth rate, which is an important element of the regressors in Eq. (8), we present separate regression results below for the parameters of θ equals 7.00 and θ equals 9.00.

5 Estimation Results

The spatial equilibrium, Eq. (8), dictates our choice of variables in the empirical analysis. We present results for two separate trade elasticities, θ. These are $\theta = 0.7$ and $\theta = 0.9$. For the estimation of Eq. (8), we work with the difference of two terms as the dependent variable. The first term of the dependent variable is the difference between the housing price growth rate in MSA j and the national housing price growth rate. The second term in the dependent variable is the difference between the MSA goods price growth rate in city j and the national goods price growth rate.

The first independent variable, which we refer to as Regressor 1, is the first term in brackets on the right side of Eq. (8). Similarly, the second term in brackets on the right side of Eq. (8) is referred to in the tables below as Regressor 2. The third term on the right side of Eq. (8) comprises two additional regressors that are proxies for spatial complexity, regulation, and housing supply factors at the MSA-level and national level, respectively. This version of Eq. (8) is first estimated by OLS with fixed effects for each of the years and MSAs in the sample, and results are presented in column 1 of Table 3 (for $\theta = 0.7$) and Table 4 (for $\theta = 0.9$). In these regression results, all of the regressors have the correct sign.

For both trade elasticities, the parameter estimates on Regressor 1, Regressor 2, and the MSA level complexity term, are all statistically significant, and the goodness-of-fit estimate is 0.214. While these results are intuitive based on the predictions of Eq. (8), it is possible that endogeneity of the underlying variables in these regressors could be leading to biased estimates. In other words, endogeneity bias might lead us to reject the theory underlying Eq. (8) in terms of the signs and significance of the parameter estimates. To investigate this possibility, below we explore an IV approach and a Generalized Methods of Moments (GMM) approach.

As a starting point for the IV and GMM models, we explore the first stage regressions for each endogenous variable (i.e., Regressor 1 and Regressor 2). Table 5 presents the first stage regressions for each of these two endogenous regressors. In the first column (for Regressor 1), the completed highway miles per capita and the log of the ratio of MSA-level military contracts to the average MSA military contracts are statistically significant. While the remaining instruments for this first stage regression are insignificant, the F-statistic p-value is very small (less than 0.001), and the R-squared for this first-stage regression is 0.755. For the Regressor 2 first stage regression, shown in column 2 of Table 5, the MSA-level unavailable land area per capita instrument, and the exogenous spatial complexity variables (at the MSA-level and the national average) are statistically significant. While the R-squared is 0.166 for this first-stage regression, the p-value on the F-statistic is much smaller ($p < 0.000001$), implying the full set of instruments are jointly significant.

Given these first stage regression results support the correlation between the instruments and each of the two endogenous variables (Regressor 1 and Regressor 2), we now move to present the second stage results for the IV and GMM estimations. First, in the second columns of Table 3 (for $\theta = 0.7$), we see that the score p-value = 0.418, which implies we cannot reject the hypothesis that our overidentification restrictions are valid. Moving to the IV parameter estimates for the Regressor 1 and Regressor 2, in column 2 of Table 3, they both have the anticipated sign (i.e., positive) and are statistically significant with p-value < 0.10. The MSA-level spatial complexity variable is also positive (i.e., the anticipated sign) and signficant, with p-value < 0.01. The R-squared is 0.148 for this IV estimation when the trade elasticity, θ, is 0.7.

The third column of Table 3 presents the GMM results for the case of $\theta = 0.7$. The p-value for the J-statistic is 0.398, again implying we cannot reject the hypothesis that our overidentification restrictions are valid. Turning to the GMM parameter estimates for Regressor 1 and Regressor 2, they are both the anticipated sign (positive) but are statistically significant with a lower p-value than the IV estimates. With the GMM results, Regressor 1 and Regressor 2 have $p < 0.05$. Once again, the spatial complexity term has a positive and significant coefficient ($p - value < 0.01$). The R-squared for the GMM estimation is 0.141.

In columns 2 and 3 of Table 4, we present the IV and GMM results, respectively, for the larger trade elasticity, $\theta = 0.9$. In column 2 of Table 4, the IV estimates imply that the coefficients on Regressor 1 and Regressor 2 are positive and significant (with $p < 0.1$ and $p < 0.05$, respectively). The MSA-level spatial complexity term is positive and significant (p-value $<$ 0.01). The p-value of the score is 0.467, so we cannot reject the validity of the overidentification restrictions. The R-squared in this IV model is 0.112.

Finally, the third column of Table 4 presents the GMM results where $\theta = 0.9$. The parameter estimates on both Regressor 1 and Regressor 2 are positive and statistically significant ($p < 0.05$). While the R-squared is smaller (0.0889) than that of the IV model, the overidentification restrictions cannot be rejected once again ($J-$statistic $=$ 0.464). The coefficient on the MSA-level spatial complexity term is similar here to the IV model in terms of the sign and significance.

In sum, the first two regressors on the right side of Eq. (8) have the correct sign and are statistically significant, regardless of the trade elasticity being 0.7 or 0.9, and this result is robust to various estimation techniques (OLS, IV, and GMM). The OLS and GMM estimations lead to lower $p-$values on these regressors than the IV model. The first stage regressions on these instruments seem to perform fairly well. The bottom line is that the data seems to support the theory we have developed in Eq. (8). We discuss the implications of this in the conclusion section below.

An implication of these estimates is that the behavioral model helps in addressing another issue. If we were to interpret the price of housing as the user cost of housing, then expected capital gains on housing (from increases in the third term in Regressor 2) reduce its user cost. For spatial equilibrium, this is consistent with a lower growth rate of per capita real income in the same city. In other words, and without making a causal claim (but see Glaeser and Gyourko (2017) and Hsieh and Moretti (2017)), expected capital gains in housing are associated with lower real income growth. Additionally, when GDP grows faster in a particular MSA than the nationwide average, one expects faster growth in house prices relative to national house prices, after filtering out changes in the growth rate of local goods prices relative to national goods prices.

6 Conclusions

This is the first paper, to the best of our knowledge, which aims at estimating an equilibrium urban macro model that links a city's presence in domestic trade to its house price growth rate performance. We estimate a spatial equilibrium equation based on our urban macro model. Our primary empirical findings confirm the comparative statics implications of our theoretical model. In the spatial equilibrium equation, we have controlled for endogeneity with IV and GMM approaches.

In addition to our development of the theoretical equilibrium urban macro model in this context, one of our other contributions is our merging of a set of novel data for testing the theory. Our instruments, including our development of military contracts data aggregated to the MSA level, and cancer death rates at the MSA level, are novel. We also adapt a market access approach to aid in our development of consumer prices estimates at the MSA level. The lack of availability of comprehensive consumer prices data at the MSA level from U.S. statistical agencies necessitates this type of alternative approach for empirically estimating the spatial equilibrium equation.

It would be interesting to explore the potential of the model to explain housing price dynamics and economic growth in a number of truly global cities, such as New York, San Francisco, Vancouver, London, Singapore, Hong Kong, etc. In those cities and many others, it is not only trade but also foreign investment in housing and real estate that plays an important but not well understood role. These issues clearly deserve attention in future research. At least in the U.S. context, inclusion of such larger MSAs that are comprised of many smaller cities would require the ability to merge data on many different variables with MSA definitions that are consistent across variables. Given that our data for the largest cities are drawn from sources relying on several different definitions, a first step in improving the data availability for the largest cities might be to devote resources for facilitating a broad and collaborative approach to data collection and merging across federal and local government agencies.

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8 Appendix A (Not for Publication): The Urban Production Structure

We develop first the case where all cities are autarkic, that is no intercity trade, and cities produce both manufactured tradeable goods, and use them in turn to produce the composite used for consumption and investment. Each of the manufactured tradeable goods, $j = X, Y$, is produced by a Cobb-Douglas production function, with constant returns to scale, using a composite of raw labor and physical capital, with elasticicities $1-\phi_J$, and ϕ_J, respectively, and a composite made of intermediates. The shares of the two composites are $u_J, 1-u_J$ respectively. There exists an industry $J-$specific total factor productivity, Ξ_{Jt}. Production conditions for each of two industries J are specified via their respective total cost functions:

$$B_{Jt}(Q_{Jt}) = \left[\frac{1}{\Xi_{Jt}}\left(\frac{W_t}{1-\phi_J}\right)^{1-\phi_J}\left(\frac{R_t}{\phi_J}\right)^{\phi_J}\right]^{u_J}\left[\sum_m P_{Zt}(m)^{1-\sigma}\right]^{\frac{1-u_J}{1-\sigma}} Q_{Jt}, \tag{10}$$

where Q_{Jt} is the total output of good $J = X, Y$, P_{Zt} is the price of the typical intermediate, elasticity parameters u_J, ϕ_J satisfy $0 < u_J, \phi_J < 1$, and the elasticity of substitution in the intermediates composite σ is greater than 1. The TFP term Ξ_{Jt}, summarizes the effect on industry productivity of geography, institutions and other factors that are exogenous to the analysis.

Each of the varieties of intermediates used by industry J are produced according to a linear production function with fixed costs (which imply increasing returns to scale), with fixed and variable costs incurred in the same composite of physical capital and raw labor that is used in the production of manufactured goods X and Y. The shares of the productive factor inputs used are the same as, ϕ_J and $1-\phi_J$, $J = X, Y$, respectively.[20] The respective

[20] This may be generalized to allow for input-output linkages by requiring (see also Fujita, *et al.* (1999), Ch. 14), that each intermediate good industry use its own composite as an input. This is accomplished by introducing as an additional term $\left[\int_0^{M_{it}} p_{it}^{1-\epsilon_i}\right]$ on the r.h.s. of the cost function $b_{it}(Z_{Jt})$.

total cost function is

$$b_{it}(Z_{Jt}(m)) = \frac{f + cZ_{Jt}(m)}{\Xi_{Jt}} \left[\left(\frac{W_t}{1-\phi_J} \right)^{1-\phi_J} \left(\frac{R_t}{\phi_J} \right)^{\phi_J} \right],$$

and $Z_{Jt}(m)$, the quantity of the input variety m used by industry $J = X, Y$. Its price is determined in the usual way from the monopolistic price setting problem [Dixit and Stiglitz (1977)] and it is equal to marginal cost, marked up by $\frac{\sigma}{\sigma-1}$:

$$P_{Z,J,t} = \frac{\sigma}{\sigma-1} \frac{c}{\Xi_{Jt}} \left(\frac{W_t}{1-\phi_J} \right)^{1-\phi_J} \left(\frac{R_t}{\phi_J} \right)^{\phi_J}.$$

At the monopolistically competitive equilibrium with free entry, each of the intermediates is supplied at quantity $(\sigma - 1)\frac{f}{c}$, and costs $\frac{\sigma f}{\Xi_{Jt}} \left(\frac{W_t}{1-\phi_J} \right)^{1-\phi_J} \left(\frac{R_t}{\phi_J} \right)^{\phi_J}$ per unit to produce. Its producer earns zero profits.

9 Tables

Notes to Tables

- Notes to Tables 1 and 2:

  "gdp_gr" stands for growth rate of MSA GDP per capita. "hpi_gr" stands for growth rate of the MSA house price index. "all_cancer_pcap_gr" stands for the growth rate of per-capita cancer deaths in the MSA. "contracts_gr" is the growth rate of military contracts awarded to firms in the MSA. "leccnp_percapita" is the number of miles of completed highways in the MSA, per million population. "unaval_percap" is the unavailable land area in the MSA, per million population. "employ" is the level of employment in the MSA. "pit_700_gr" is the growth rate of the MSA level goods price index, where $\theta = 7$. "pit_900_gr" is the growth rate of the MSA level goods price index, where $\theta = 9$.

- Notes to Tables 3 and 4:

  Tables 3 and 4 show the first-stage regression results under the assumptions that $\theta = 7$ and $\theta = 9$, respectively. "gdp_gr_inst" is the difference between the growth rate of MSA-level military contracts awarded and the national average growth rate of military contracts awarded. "cpi_700_gr_inst" is the difference between the MSA-level cancer deaths (per-capita) growth rate and the national-level cancer deaths (per-capita) growth rate when $\theta = 7$. "cpi_900_gr_inst" is the difference between the MSA-level cancer deaths (per-capita) growth rate and the national-level cancer deaths (per-capita) growth rate when $\theta = 9$. "unaval_inst" is the natural log of the ratio of MSA-level unavailable land area per million population and the national average unavailable land area per million population. "leccnp_percapita" is the number of miles of completed highways in the MSA, per million population. "contracts_inst" is the natural log of the ratio of MSA-level military contracts awarded to national-level military contracts awarded. "employ_term" stands for $\ln\left[N_{i,t}^{\frac{1}{2}}\right]$."employ_avg_term" stands for $\ln\left[N_{\mathrm{n},t}^{\frac{1}{2}}\right]$.Regressor 1 stands for: $\left[\ln\left[\frac{P_{i,t}}{P_{n,t}}\right] - [GR_{t+1,t}(P_i) - GR_{t+1,t}(P\mathrm{u})] - \ln\left[\frac{P_{i,G,t}}{P_{n,G,t}}\right]\right]$.Regressor 2 stands for: $\left[[GR_{t+1,t}\Upsilon_j - GR_{t+1,t}(\Upsilon\mathrm{n})] - \ln\left[\frac{P_{i,t}}{P_{n,t}}\right]\right]$.

- Notes to Tables 5 and 6:

  Tables 5 and 6 show the regression results for the spatial equilibrium equation, under the assumptions that $\theta = 7$ and $\theta = 9$, respectively; and $S = \beta$ in both tables. Columns 1, 2, and 3 show the estimation results from using Ordinary Least Squares regressions (OLS), the second stage results for two-stage least squares regressions (2SLS), and Generalized Methods of Moments (GMM). All models include fixed effects for MSAs and years, and robust standard errors, using annual data for the years 2003-2017. In all 3 models, Regressor 1 and Regressor 2 have the anticipated sign based on the theory from Equation (8), and are statistically significant. score_pvalue_700 and jstat_pvalue_700 are the $P-$values for the score and the J statistic, respectively, for $\theta = 7$; and score_pvalue_900 and jstat_pvalue_900 are the $P-$values for the score and the J statistic, respectively, for $\theta = 9$. Since all of these p-values are greater than 0.05, for the 2SLS and GMM models we cannot reject the hypothesis that the overidentification restrictions are valid.

Table 1: Means and Standard Deviations of Data, $\theta = 7, 9$

	(1) All MSAs	(2) New England	(3) Mideast	(4) Great Lakes	(5) Plains
gdp_gr	3.63	3.13	3.35	2.87	3.74
	(3.910)	(2.146)	(2.205)	(3.779)	(3.519)
hpi_gr	2.01	1.06	1.87	0.87	1.84
	(7.032)	(4.848)	(4.625)	(4.615)	(3.352)
all_cancer_pcap_gr	0.21	-0.18	0.11	0.44	0.28
	(3.281)	(3.972)	(3.073)	(2.346)	(2.526)
contracts_gr	515.28	729.07	574.64	335.46	391.98
	(2337.3)	(3082.2)	(2256.0)	(1640.3)	(1589.8)
leccnp_percapita	39.20	36.69	33.41	34.37	23.29
	(75.63)	(27.78)	(53.20)	(57.56)	(43.15)
unaval_percap	0.71	0.42	0.80	0.51	0.32
	(0.929)	(0.340)	(0.892)	(0.823)	(0.393)
employ	3.4e+05	4.2e+05	3.3e+05	2.9e+05	3.2e+05
	(427940.3)	(166380.5)	(337264.5)	(317509.1)	(460365.0)
pit_700_gr		-0.40	-0.42	-0.37	-0.50
		(0.280)	(0.280)	(0.484)	(0.365)
pit_900_gr		-0.31	-0.32	-0.29	-0.39
		(0.221)	(0.232)	(0.400)	(0.300)
N	2587	55	285	449	311

mean coefficients; sd in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: Means and Standard Deviations of Data (continued), $\theta = 7, 9$

	(1) Southeast	(2) Southwest	(3) Rocky Mountains	(4) Far West
gdp_gr	3.61	4.00	4.64	4.25
	(4.009)	(4.572)	(4.873)	(4.295)
hpi_gr	1.98	2.46	3.46	3.25
	(7.423)	(6.571)	(6.940)	(12.71)
all_cancer_pcap_gr	0.31	-0.02	-0.05	0.05
	(3.335)	(2.702)	(6.609)	(2.972)
contracts_gr	562.69	584.05	531.38	630.89
	(2826.0)	(2454.6)	(2074.4)	(2434.9)
leccnp_percapita	38.79	46.94	96.15	32.38
	(66.29)	(56.27)	(177.4)	(88.34)
unaval_percap	0.83	0.45	1.27	1.09
	(0.900)	(0.701)	(1.127)	(1.357)
employ	3.3e+05	4.6e+05	2.8e+05	3.9e+05
	(397004.7)	(666362.3)	(362860.5)	(436607.5)
pit_700_gr	-0.47	-0.53	-0.64	-0.56
	(0.473)	(0.570)	(0.464)	(0.445)
pit_900_gr	-0.36	-0.40	-0.50	-0.42
	(0.383)	(0.453)	(0.372)	(0.368)
N	769	291	155	272

mean coefficients; sd in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: $S = B$ First Stage Regressions, MSA and Year fixed effects, Robust Standard Errors, Dependent Variable defined p. 17. $\theta = 7$

	(1) Regressor 1	(2) Regressor 2
gdp_gr_inst	0.00000111	-0.0000121
	(0.764)	(0.706)
cpi_700_gr_inst	-0.00163	-0.0168
	(0.505)	(0.474)
unaval_inst	0.226	24.50**
	(0.735)	(0.001)
leccnp_percapita	0.00954**	0.0573
	(0.007)	(0.147)
contracts_inst	0.0225**	0.00513
	(0.003)	(0.944)
employ_term	0.181	64.62**
	(0.864)	(0.000)
employ_avg_term	-0.114	-32.22**
	(0.895)	(0.000)
_cons	-2.346	-448.7**
	(0.859)	(0.002)
r2	0.686	0.166
Fstat_pvalue1	0.00401	
Fstat_pvalue2		0.000000431
N	2405	2405

p-values in parentheses

$^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$

Table 4: $S = B$ First Stage Regressions, MSA and Year fixed effects, Robust Standard Errors, Dependent Variable defined p.17. $\theta = 9$.

	(1) Regressor 1	(2) Regressor 2
gdp_gr_inst	0.000000869	-0.0000121
	(0.783)	(0.706)
cpi_900_gr_inst	-0.00106	-0.0168
	(0.610)	(0.474)
unaval_inst	-0.00176	24.50**
	(0.997)	(0.001)
leccnp_percapita	0.00823**	0.0573
	(0.005)	(0.147)
contracts_inst	0.0189**	0.00516
	(0.003)	(0.943)
employ_term	-0.614	64.60**
	(0.460)	(0.000)
employ_avg_term	0.306	-32.20**
	(0.670)	(0.000)
_cons	2.062	-448.8**
	(0.844)	(0.002)
r2	0.755	0.166
Fstat_pvalue1	0.000350	
Fstat_pvalue2		0.000000442
N	2405	2405

p-values in parentheses

$^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$

Table 5: S=B Regressions with Fixed Effects for MSA and Year, Robust Standard Errors, Dependent Variable: (MSA House Price Index Growth - National House Price Index Growth) - (MSA Goods Price Index Growth - National Goods Price Index Growth). $\theta = 7$.

	(1) OLS	(2) 2SLS	(3) GMM
regressor1_700	3.163^{**}	6.642^{+}	6.621^{*}
	(0.000)	(0.070)	(0.041)
regressor2_700	0.325^{**}	0.454^{+}	0.485^{*}
	(0.000)	(0.062)	(0.041)
employ_term	42.15^{**}	39.38^{**}	38.42^{**}
	(0.000)	(0.000)	(0.000)
employ_avg_term	-2.715	2.743	-9.693
	(0.836)	(0.945)	(0.713)
_cons	-218.1^{**}	-239.4	-154.5
	(0.005)	(0.374)	(0.367)
r2	0.227	0.148	0.141
ar2			
score_pvalue_700		0.418	
jstat_pvalue_700			0.398
N	2422	2405	2405

p-values in parentheses

$^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$

Table 6: S=B Regressions with Fixed Effects for MSA and Year, Robust Standard Errors, Dependent Variable: (MSA House Price Index Growth - National House Price Index Growth) - (MSA Goods Price Index Growth - National Goods Price Index Growth) $\theta = 9$.

	(1)	(2)	(3)
	OLS	2SLS	GMM
regressor1_900	3.243**	7.855+	8.308*
	(0.000)	(0.070)	(0.047)
regressor2_900	0.337**	0.496*	0.520*
	(0.000)	(0.035)	(0.028)
employ_term	42.79**	41.76**	41.36**
	(0.000)	(0.000)	(0.000)
employ_avg_term	-2.967	-0.959	-4.494
	(0.822)	(0.981)	(0.900)
_cons	-220.0**	-229.2	-204.7
	(0.005)	(0.393)	(0.397)
r2	0.214	0.112	0.0889
ar2			
score_pvalue_900		0.467	
jstat_pvalue_900			0.464
N	2422	2405	2405

p-values in parentheses

$^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$