International and Intercity Trade, and Housing Prices in US Cities\textsuperscript{1}

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\textsuperscript{1}We acknowledge with thanks that we benefited from very insightful conversations with Costas Arkolakis, Federico Esposito and Vernon Henderson, from assistance with the data by Albert Saiz, and from comments by Kevin Patrick Hutchinson, Zack Hawley and other participants at our presentations at the Urban Economics Association, Minneapolis, November 2016, the ASSA/AREUEA meetings, Chicago, January 2017, participants at C.R.E.T.E., Milos, Greece, July 2017, especially Elias Dinopoulos, and at HULM 2017, Philadelphia, especially Satyajit Chatterjee and Morris Davis. We are especially grateful to the following individuals for lending us data: Morris Davis, Roberto Cardarelli, Lusine Lusinyan, and Steven Yamarik. We remain solely responsible for the content.

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Abstract

International trade models typically consider countries exchanging goods/services, while urban models often examine the consequences of domestic trade for city structure. Relatively little known research synthesizes these to allow for shocks propagating domestically with both domestic and international trade. One exception is Autor et al. (2013), who examine how Chinese imports impact US domestic labor markets.

We consider how city-to-city domestic trade and city international exports impact city Gross Domestic Product (GDP) and housing price growth. We develop a theoretical model of trading cities, domestically and internationally, and explore its empirical predictions. We propose and estimate several empirical models. Using instrumental variables (IV), we identify city-level GDP growth impacts on city house price growth. This equation follows from imposing spatial equilibrium across cities. A second equation examines how international exports from a city, transfers, and domestic shipments impact city-level GDP. We also consider a third set of equations, which explores how economic integration, domestic and international, affects city-level GDP growth. In general, our empirical estimation results confirm the signs/magnitudes predicted by the theory, and imply that labor market shocks in trading cities affect city-level GDP, which in turn impacts housing prices. Our simulations show that a shock to international exports has the greatest positive effect on house price growth, followed by domestic shipments. Our theoretical approach, synthesis of city-level data, and empirical analysis are completely novel.
1 Introduction

An economy’s cities are its vibrant hubs of economic activity and culture. They host a large and indeed ever increasing share of its 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 as well as to the rest of the world, thus allowing their economies to import goods that are consumed by their population and industries. Production of tradeable and non-tradeable goods and services typically generates demand for imports of intermediate goods, which are supplied by other cities in the economy and the rest of the world. Urban economic activity provides employment and is accommodated by each city’s real estate sector. Real estate encompasses housing and non-housing structures. Commercial real estate prices and rents, and housing prices and rents, as well as land values are all key determinants of the cost of urban production and urban living. Urban economies are profoundly open to domestic and international competition in their export industries.

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 very recent literature that links local housing markets and in international 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 started in 2001 and is reported annually for 381 US MSAs.\(^4\) A second source is little known data on merchandise exports of different US MSAs to the world economy.\(^5\) Furthermore, data on commodity flows from state to state, and within MSA and within state shipments, allow us to estimate the interactions between trade, on one hand, and labor and housing markets on the other, at alternative levels of aggregation.\(^6\) Other data from

\(^4\)http://www.bea.gov/newsreleases/regional/gdpMetro/gdpMetroNewsRelease.htm
\(^5\)http://www.trade.gov/mas/ian/metroreport/
\(^6\)Commodity Flow Survey (CFS) is conducted every five years, in years ending in “2” and “7”. Thus,
the Brookings Institute also detail MSA exports based on the production location of the exported products. Adding up the MSA to MSA shipments (including within-MSA), plus the MSA to each region of the world exports would give us an estimate of overall (domestic plus international) MSA-level gross sales of traded goods and services.

Availability of trade data, intercity shipments as well as international exports data, allow us another glimpse at the forces affecting housing costs. For example, a positive shock to international exports of a particular city translates to shocks to the demand for labor and housing in that city. Thus, trade data may be brought to bear as a direct proxy of contemporaneous economic interaction across economic conditions in different cities.

The remainder of this paper is organized as follows. First, we outline a static model of an economy made up of cities engaged in intercity and in international trade and explore predictions it offers for structuring an empirical investigation. The model predicts that there are structural differences across cities of different types in the determination of city GDP on account of intercity trade, and how GDP growth affects the growth of city-level house prices. The paper also estimates the respective structural equation for GDP determination. 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 have not been analyzed. A third equation derives from modeling urban growth. The paper next reviews the data and discusses our empirical results.

Our interpretation of the empirical findings is that since trading cities have more channels through which an employment shock can be absorbed, there is much less of an impact that is passed through to the housing markets and therefore house price growth may be much more
insulated. To the best of our knowledge, the paper’s approach is completely novel; we are unaware of any previous research that synthesizes the intercity trade data, city-level housing price data, and international exports data, nor of their role in estimation of city GDP.

2 Literature Review

There is relatively little literature that emphasizes empirically the structural implication of intercity trade. Pennington-Cross (1997) focuses on the development of an exports price index, in the context of estimating external shocks to a city’s economy. There are several later applications of this index, including 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. 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.

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, using the earlier exports data set from the ITA. Ferris and Riker (2015) study the relationships between exports and wages, using the 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. Finally, Vachon and Wallace (2013) use the exports data to assess how globalization affects unionization in 191 MSAs.

Finally, a more recent paper by Li (2017) uses a very rudimentary empirical analysis to motivate her 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
Our understanding of export-oriented cities would benefit from further analytical and empirical attention, in view of the sparseness of published research integrating theoretical underpinnings with rigorous empirical modelling on house prices, GDP, and exports at the MSA level, together with the limitations of some of the other exports data sources.

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 Static Model of an Urban Economy

We start with a basic model [Ioannides (2013), Ch. 7] with two types of cities in a static context: cities specialize either in the production of final good $X$ or final good $Y$. Residents of all cities consume quantities of the two final goods and housing services $h(ℓ)$, defined in terms of units of land. Residents have identical preferences, defined by an indirect utility function as follows:

$$U = \beta^\alpha \left[ (1-\alpha)^{1-\alpha} P_X^{-\alpha} P_Y^{-(1-\alpha)} \right]^{1-\beta} R(\ell)^{-\beta} \Upsilon(\ell), \ 0 < \alpha, \beta < 1,$$

where $P_X$, $P_Y$, and $\Upsilon$ are the price of good $X$, good $Y$, and income per person, respectively. $R(\ell)$ is the rent of land at distance $\ell$ from the city center, and $\Upsilon(\ell) = w(1 - \kappa \ell)$, where $w$ is the wage rate and $\kappa$ the unit transport cost in terms of time. Spatial equilibrium within each city is defined in terms of the variation of the land rent with distance from the CBD. That is, for spatial equilibrium,

$$R(\ell) = R_0 (1 - \kappa \ell)^{\frac{1}{\pi}},$$

where $R_0 = R(0)$ denotes the rent of land at the CBD. Individuals’ demands $(X, Y, h(\ell))$ are given by Roy’s identity:

$$X_j = \alpha (1-\beta) \frac{\Upsilon}{P_X}; \ Y_j = (1-\alpha)(1-\beta) \frac{\Upsilon}{P_Y}; \ h(\ell) = \beta \frac{\Upsilon_j(\ell)}{R_j(\ell)},$$

where $j = X, Y$ denotes goods (but all city type, when cities specialize fully).\(^7\) The demand for land, in particular, is given by: $h(\ell) = \frac{\beta w}{R_0^\pi} (1 - \kappa \ell)^{-\frac{1-\beta}{\pi}}$.

Because of the analytical complexity of the model with housing demand being elastic, we simplify by adopting inelastic housing demand.\(^8\) In that case, the indirect utility function becomes simply:

$$U = \alpha^\alpha (1-\alpha)^{1-\alpha} P_X^{-\alpha} P_Y^{-(1-\alpha)} \Upsilon.$$

\(^7\)The production of each good requires raw labor and intermediate varieties, which are produced with raw labor using increasing returns to scale production functions. See Ioannides (2013), Ch. 7, Eq. (7.15). The preferences assumed here are more general than in Ioannides (2013), Ch. 7, which assumes that population density (lot size) is set equal to 1.

\(^8\)A more general model with elastic housing demand is fleshed out further below in the paper, section 3.2, in the case of a growing urban economy.
Income per person in each city type is defined as total income per person, which consists of labor income plus land rental income divided by city population, which is denoted by \( N_X, N_Y \) for each type of city. For the simpler model, populations in each city type, \( N_j, j = X, Y \), and physical city sizes, \( \bar{\ell}_j = \left( \frac{N_j}{\pi} \right)^{\frac{1}{2}} \) imply an expression for net labor supply:

\[
H_c(N_j) = \int_0^{\left( \frac{N_j}{\pi} \right)^{\frac{1}{2}}} 2\pi\ell(1 - \kappa'\ell) d\ell = N_j(1 - \kappa'N_j^{\frac{3}{2}}), \tag{4}
\]

where \( \kappa' = \frac{3}{2}\pi^{\frac{1}{2}} \). Assuming that the value of land at the fringe of the city is given by the agricultural rent, \( R_{a,j} \), allows us to solve for physical city size. That is, we have:

\[
R_j(\bar{\ell}) = R_{a,j} = R_{0,j} \left( 1 - \kappa'\bar{\ell} \right) W, \tag{5}
\]

where \( W \) denotes the nominal wage rate. From this and the previous equations, we may solve for \( R_{0,j} \) and \( \bar{\ell}_j \) as functions of \( (N_j, R_{a,j}) \). Land rental income is given by

\[
Y_{j,\text{land}} = \frac{1}{N_j} \int_0^{\bar{\ell}_j} 2\pi\ell R_j(\ell) d\ell = \frac{1}{2}\kappa'WN_j^{1/2}. \tag{6}
\]

Labor income per person, \( Y_{j,\text{labor}} \) is equal to wage rate times the labor supply net of commuting costs (which are expressed in terms of time), on the supply side, and to the value of sales of the good a city is specializing in, on the demand side, which in turn is spent on both final goods. Thus, allowing for transfers from elsewhere in the economy, and denoting net transfers per person into city \( j \) by \( T_j \), total income per person is equal to labor income per person, \( Y_{j,\text{labor}} \), plus land rental income per person, \( Y_{j,\text{land}} \), plus transfers per person, \( T_j \):

\[
Y_j = Y_{j,\text{land}} + Y_{j,\text{labor}} + T_j. \tag{7}
\]

We note that GDP per person is observable and may be used in the place of \( Y_j \). Transfers account for income that originates outside the particular city, but may depend on city demographics. Also, we experiment with income per employee, which is appropriate because congestion is associated with travel to work.

Because of complexity of analytical expressions, the assumption is often made that land income is redistributed equally among all residents rather than being earned by absentee landlords. In such a case, income net of commuting and land costs may be expressed in terms
of population and the price of the good in which the city specializes; see below [Ioannides (2013), p. 315]. Because of intraurban transportation costs, which take the form of time, labor supply, that is available labor minus commuting costs, depends upon the geographic complexity of the city. E.g., with linear commuting costs, assumed above, $K(\ell) \equiv \kappa \ell$, and inelastic demand for land, net labor supply is given by (4) [ibid., p. 300, eq. (7.2)]. This expression is more complicated in the exact case of our model where housing demand is elastic, or when city geography is more complicated. Thus, GDP supply per person in a city of type $j$ is given by $\frac{1}{N_j}F(H_c(N_j))$, where $F(\cdot)$ denotes the aggregate production function and $H_c(N_j)$ denote the net labor supply in city $j$ given by (4). Under the assumptions of Ioannides (2013), Chapter 7, GDP supply per person in city $j$, gross of transfer income, is given by:

$$\Upsilon_j = B_j \delta_j P_j N_j^{\frac{1-u_j}{\sigma-1}} (1 - \kappa' N_j^{1/2})^{\frac{\sigma-u_j}{\sigma-1}}, \quad j = X, Y,$$

(8)

where $B_j$ is a function of technology parameters, $\delta_j = 1 + (n_j - 1)\tau^{\sigma-1}$ a function of the number of cities of each type and intercity iceberg shipping costs parameter for intermediates, $u_j$ is the elasticity of raw labor in the Cobb-Douglas production function of good $j$, $1 - u_j$ the elasticity of the CES aggregate of intermediates used in production of each good, and $\sigma$ the elasticity of substitution among the intermediates. This particular result serves to underscore that city geography, and more generally congestion, have complex effects on city GDP supply per person.

For national equilibrium in an economy consisting of $n_X$ cities of type $X$ and $n_Y$ cities of type $Y$, total population $N$ is allocated to all cities,

$$n_X N_X + n_Y N_Y = \bar{N}.$$

(9)

In the absence of shipments to the rest of the world (ROW), all exports of good $X$ are purchased by cities of type $Y$, and all exports of good $Y$ are purchased by cities of type $X$, the total spending on good $Y$ by all cities is equal to the total spending on good $X$, where $X, Y$ denote, respectively, the production of good $X$, good $Y$ by each city of the respective type. That is:

$$(1 - \beta)(1 - \alpha)n_X X_P X = (1 - \beta)\alpha n_Y Y_P Y.$$

(10)
Spatial equilibrium among cities is expressed as equalization of utility across cities of different types. Adopting Ioannides (2013), section 7.5, with the expression for income per person in we have that:

\[ U_X = C_X \delta_X^{1-u_X} \left( \frac{P_X}{P_Y} \right)^{1-\alpha} N_X^{1-u_X} (1 - \kappa' N_X^{1/2})^\sigma \; \alpha^{u_X} \;
\]

\[ U_Y = C_Y \delta_Y^{1-u_Y} \left( \frac{P_X}{P_Y} \right)^{1-\alpha} N_Y^{1-u_Y} (1 - \kappa' N_Y^{1/2})^\sigma \; \alpha^{u_Y} \; \]

where \( C_X, C_Y \) are suitably defined constants, and \( \delta \)'s reflect shipping costs for intermediates and the numbers of cities of each type.\(^9\) Whereas it would be straightforward to work with these utility functions in order to obtain spatial equilibrium conditions, we postpone such an exercise for the more general model we develop next.

Working from (10) we may express aggregate demand in \( X \)– type cities per person in terms of total spending on good \( X \) by all other cities per person. This may be proxied by shipments per capita \( S_X \) from cities of type \( X \) to all other cities, \( S_X = (1 - \beta)\alpha \frac{n_Y}{n_X N_X} Y P_Y \), plus the value of per capita shipments to the rest of the world (ROW), \( ex_X \) from a city of type \( X \), plus per capita transfers from the rest of the domestic economy, \( T_X \). That is, respectively for each city type \( X, Y \), we have:

\[ \Upsilon_X = (1 - \beta)\alpha \frac{n_Y}{n_X N_X} Y P_Y + T_X + ex_X; \Upsilon_Y = (1 - \beta)(1 - \alpha) \frac{n_X}{n_Y N_Y} X P_X + T_Y + ex_Y. \]  

(13)

This will be generalized further below to allow for imports from the ROW. We note that the terms \( \frac{n_Y}{n_X N_X} Y P_Y, \frac{n_X}{n_Y N_Y} X P_X \) may be directly proxied by the value of shipments from each city to all other cities.

At a first level of approximation, we may ignore city type\(^10\) and use Eq.’s (13) to motivate a single regression equation for each city that expresses the aggregate demand for GDP per capita in city \( j \) in terms of shipments to other cities, \( S_j \), per capita transfers \( j \), \( T_j \), and exports by city \( j \), \( ex_j \), to the rest of the world:

\[ \Upsilon_j = \gamma_1 S_j + \gamma_2 T_j + \gamma_3 ex_j. \]

(14)

\(^9\)Iceberg shipping costs for final products are reflected on the equilibrium terms of trade; see Ioannides (2013), Section 7.5.

\(^10\)City types are hard to assign, because only a small share of city employment may be reliably linked to a city’s export industries for most cities. See Ioannides (2013), Chapter 7.
This equation expresses a key feature of the system of cities model: GDP is determined by equilibrium in the goods markets, via the interaction of each city with all other cities, and equilibrium within each city housing market, which enters the definition of $\gamma_j$, aggregate income per person. Each city supplies goods and services to all other cities and buys goods and services from them. Since in an economy like that of the US cities are very open (within the domestic economy) economic entities — in terms of movement of commodities, of people and of knowledge flows — city GDP determination is a critical relationship, much like national income determination of internationally open economies. Here all intercity transactions are expressed as trades in the national currency. It readily follows from (7) and (14) that the conditions $\gamma_2 = \gamma_3 = 1$ are testable empirically.

While the model incorporates spatial equilibrium within each city, the urban system is in equilibrium if identical individuals are indifferent among all city locations. Equalizing utility across all cities at all times yields the inter-city spatial equilibrium condition. Taking first differences allows us to define the growth rate of land value, $R_{0,j}$, for each city relative to a reference urban land value growth rate for the entire system of cities, $R_{0,n}$, in terms of the growth rate of the price index for city $j$, $P_j$, relative to an urban price index, $P_u$, and the growth rate of per capita income relative to the growth rate of national per capita income, $\gamma_n$:

$$GR_{t+1,t}(R_{0,j}) - GR_{t+1,t}(R_{0,n}) = [GR_{t+1,t}(P_j) - GR_{t+1,t}(P_u)] + [GR_{t+1,t}\gamma_j - GR_{t+1,t}(\gamma_n)].$$

(15)

Eq. (14–15) can be taken to the data. Both these equations are derived using a simplified framework for the purpose of demonstrating the empirical potential of the model. Next, we introduce a more general model for individuals’ behavior which implies a more complicated spatial equilibrium condition, in which (15) may be nested.
3.2 A Model of Urban Economic Integration, Specialization and Economic Growth

The exposition that follows extends the main model in Ioannides (2013), Chapter 9, in order to allow for international trade.\textsuperscript{11} It is a dynamic model that allows for differences across cities in terms of city-specific total factor productivities, which will be discussed further below, and of congestion parameters $\kappa_i$. It assumes that individuals are free to move across cities, thus spatial equilibrium is imposed, that is: individuals are indifferent as to where they locate. That is, individuals’ lifetime utilities are equalized across all cities. This implies in turn conditions on intercity wage patterns. Similarly, if capital is perfectly mobile, it will move so as pursue maximum nominal returns and in the process equalize them across all cities.

This section aims at obtaining, first, a more general expression for spatial equilibrium and its implications for the growth rate of the price of land (or housing), and second, more general expressions for the growth rate of city GDP for cities engaging in domestic trade as distinct from those engaging in international trade.

A number of individuals $N_t$ are born every period and live for two periods. The economy has the demographic structure of the overlapping generations model. We assume that individuals born at time $t$ work when young, consume nonhousing and housing out of 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. We assume Cobb-Douglas preferences over first- and second-period consumption for the typical individual,

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

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

Net labor supplied by the young generation in a particular city at $t$ is given by $H_t = N_t \left(1 - \kappa N_t^{1/2}\right)$, with $N_t$ the number of the members of the young generation in a particular

\textsuperscript{11}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.
city at \( t \), \( \kappa \equiv \frac{2}{3} \pi^{-\frac{1}{2} \kappa'} \), and \( \kappa' \) the time cost per unit of distance traveled.

If \( W_t \) denotes 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 as per 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 size. 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, according to (6), in terms of the number of young residents as \( \frac{1}{2} \kappa W N_t^2 \). This yields first period net labor income per young resident, after redistributed land rentals and net of individual commuting costs, of \( \left( 1 - \kappa N_t^\frac{1}{2} \right) W_t \). With a given wage rate, individual income declines with city size, other things being equal, entirely because of congestion. But, there are benefits to urban production which are reflected on the wage rate.

Let \( R_{t+1} \) be the total nominal return to physical capital, \( K_{t+1} \), in time period \( t + 1 \), that is held by the member of young generation at time \( t \). The indirect utility function corresponding to (16) is:

\[
V = R_{t+1}^{S(1-\beta)} P_{G,t}^{-(1-S)\beta} P_{G,t+1}^{-S\beta} \left( 1 - \kappa N_t^{\frac{1}{2}} \right) W_t, \tag{17}
\]

where we assume that the price of consumption is normalized to 1. We assume that capital depreciates fully in one period. The young maximize utility by 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 \( \Xi_{jt} \)'s,\(^{12}\) are the most advantageous, and capital will seek to locate

\(^{12}\)See Appendix A for details on the specification of the urban production structure and clarification of the role of the industry-specific TFP functions \( \Xi_{jt} \)'s.
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. 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 $\kappa$.

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 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.

### 3.2.1 Spatial Equilibrium

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

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

(18)

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\textsuperscript{13} across all city types, that is:

\[ R_t = R_{Xt} = R_{Yt}. \]

Spatial equilibrium for individuals requires that indirect utility, (17), be equalized across all cities. In view of free capital mobility, spatial equilibrium across cities of different types requires that:

\[
P_{G,X,t}^{-1(1-S)\beta} P_{G,X,t+1}^{-S\beta} \left(1 - \kappa X^{\frac{1}{Xt}}\right) W_{Xt} = P_{G,Y,t}^{-1(1-S)\beta} P_{G,Y,t+1}^{-S\beta} \left(1 - \kappa Y^{\frac{1}{Yt}}\right) W_{Yt}.
\]

(19)

By taking logs we have:

\[
-(1 - S)\beta \ln P_{G,X,t} - S\beta \ln P_{G,X,t+1} + \ln \left(1 - \kappa X^{\frac{1}{Xt}}\right) + \ln W_{Xt}
\]

\[
= -(1 - S)\beta \ln P_{G,Y,t} - S\beta \ln P_{G,Y,t+1} + \ln \left(1 - \kappa Y^{\frac{1}{Yt}}\right) + \ln W_{Yt}.
\]

(20)

Just as in the previous section, this allows us to obtain a condition for spatial equilibrium within each city, which is written directly in terms of labor earnings. Earnings here are expressed in terms of real city output, so we deflate them in terms of a city price index. Thus, spatial equilibrium implies:

\[
GR_{t+1,t}(P_{G,j}) - GR_{t+1,t}(P_{G,n}) = -\frac{1}{S} \left[ GR_{t+1,t}(P_{j}) - GR_{t+1,t}(P_{j,u}) \right]
\]

\[
+ \frac{1}{S\beta} \left[ GR_{t+1,t}(Y_{j}) - GR_{t+1,t}(Y_{n}) \right] + \ln \left(1 - \kappa X^{\frac{1}{Xt}}\right) - \ln \left(1 - \kappa N^{\frac{1}{Nt}}\right).
\]

(21)

We note that we have imposed spatial equilibrium. The last two terms in the right hand side of the above proxy for spatial complexity, regulation, and housing supply factors. Clearly, condition (15), obtained with a simpler behavioral model, may be nested within (21). In particular, the coefficient of \( GR_{t+1,t}(P_{j}) - GR_{t+1,t}(P_{j,u}) \), the growth rate of the city price index relative to a national average, is predicted to be positive; the coefficient of \( GR_{t+1,t}(Y_{j}) - GR_{t+1,t}(Y_{n}) \), the growth rate of income per capita relative to a national average is predicted to greater than 1.

\textsuperscript{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.
3.2.2 Intercity Trade and Determination of City GDP

Next we derive expressions for real incomes in different city types in an economy with city specialization in tradeable goods which are combined in every city to produce a composite good which is used for consumption and investment. For a city of type $X$ real income is equal to the value of the output of the good in which that city specializes, $P_X Q_X$, and for a city of type $Y$. From the definition of the numeraire, in every city: $P_X = \alpha^\alpha (1 - \alpha)^{1 - \alpha} \left( \frac{P_X}{P_Y} \right)^{1 - \alpha}$. By using the condition for spatial equilibrium, we may obtain an expression for the terms of trade, the price ratio, from which we may obtain an expression for the real income of a type $X$ city:

$$Q_X \alpha^\alpha (1 - \alpha)^{1 - \alpha} \left( \frac{P_X}{P_Y} \right)^{1 - \alpha} = \alpha^*_X Q_X^\alpha Q_Y^{1 - \alpha} \left( \frac{N_{Xit}}{N_{Yit}} \right)^{1 - \alpha},$$

where $\alpha^*_X = \alpha^\alpha (1 - \alpha)^{1 - \alpha} \left( \frac{1 - \phi_Y}{1 - \phi_X} \right)^{1 - \alpha}$. Introduction of iceberg shipping costs for tradeable goods lead a trivial modification of this condition. The real income of a city specializing in good $X$, $\mathcal{X}_t$, is expressed in terms of city populations of both types of cities, $(N_X, N_Y)$, total capital in the economy, $K_t$, and parameters as follows:

$$\mathcal{X}_t = \mathcal{N}_X \left( \frac{K_t}{N} \right)^{\alpha^*_X \phi_X + (1 - \alpha) \mu_Y \phi_Y},$$

where the auxiliary variable $\mathcal{N}_X$ is defined as a function of city sizes and parameters:

$$\mathcal{N}_X(N_X, N_Y) \equiv \alpha^*_X \xi_t N^\alpha X^{X^* + 1 - \alpha} \left( 1 - \kappa N^\alpha X \right)^{\alpha^*_X (1 - \phi_X)} N^\alpha Y^{(1 - \alpha) \mu_Y - (1 - \alpha)} \left( 1 - \kappa N^\alpha Y \right)^{(1 - \alpha) \mu_Y (1 - \phi_Y)},$$

and the function $\xi_t$, defined as a transformation of the industry-specific TFP functions $\xi_{Xt}, \xi_{Yt}$:

$$\xi_t \equiv \xi_{Xt}^{\alpha} \xi_{Yt}^{1 - \alpha} \left( \frac{\phi_X}{1 - \phi_X} \right)^{\alpha^*_X \phi_X} \left( \frac{\phi_Y}{1 - \phi_Y} \right)^{(1 - \alpha) \mu_Y \phi_Y} \left( 1 - \alpha \phi_X - (1 - \alpha) \phi_Y \right)^{\alpha^*_X \phi_X + (1 - \alpha) \mu_Y \phi_Y},$$

See Appendix A for details on the specification of the production structure and the details of how the industry-specific TFP functions enter. The TFP function $\xi_t$ is the counterpart for the integrated economy of $\xi^*_t$, defined in Ioannides (2013), Ch. 9, for the autarkic cities. The industry TFP functions enter $\xi_t$ with the same exponents as in $\xi^*_t$, but the shift factors differ.
The counterpart of (22) for $P_Y Q_Y$, the real income of a city specializing in good $Y$, is given by:

$$\mathcal{Y}_t = N_Y \left( \frac{K_t}{N} \right)^{\alpha_Y \phi_Y + (1-\alpha) \mu_Y \phi_Y},$$

where $\alpha_Y = \alpha (1 - \alpha)^{1-\alpha} \left( \frac{1 - \phi_Y}{1 - \phi_Y} \right)^\alpha$.

$$N_Y(N_X, N_Y) \equiv \alpha_Y \xi_t N_X^{\alpha_X} \left( 1 - \kappa N_X^{1/2} \right)^{\alpha_X (1-\phi_X)} N_Y^{(1-\alpha) \mu_Y + \alpha \left( 1 - \kappa N_Y^{1/2} \right)^{(1-\alpha) \mu_Y (1-\phi_Y)}}.$$

Eq. (22) and (25) define city income for cities of type $X$ and of $Y$, respectively, as functions of the economy wide capital per person, $\frac{K_t}{N}$, and of $N_X, N_Y$, which are functions of populations of both city types, of economy wide TFP, $\xi_t$, defined in (24) above, and of parameters.

Taking logs of both sides of (22) and (25) and subtracting the second from the first, we have:

$$\ln \mathcal{X}_t - \ln \mathcal{Y}_t = \ln \mathcal{N}_X - \ln \mathcal{N}_Y.$$

By using the definitions of $\mathcal{N}_X, \mathcal{N}_Y$, in (23), (26), the rhs above becomes: $\ln \alpha_X - \ln \alpha_Y + \ln N_X - \ln N_Y$.

### 3.2.3 Growth of Integrated Cities

By taking logs and time-differencing, we may express the growth of income of income for a particular city in terms of constants and the difference in the growth rate of a city of a particular type from that of the average city, and of the growth rate of aggregate capital. That is, we have for growth in income for type $X$ and type $Y$ cities,

$$\text{GR}(\mathcal{X}_{t,t}) = \ln \mathcal{X}_{t+1} - \ln \mathcal{X}_t, \quad \text{GR}(\mathcal{Y}_{t,t}) = \ln \mathcal{Y}_{t+1} - \ln \mathcal{Y}_t$$

respectively:

$$\text{GR}(\mathcal{X}_{t,t}) = \text{GR}(\xi_t) + (\alpha_X + 1 - \alpha)\text{GR}(N_{X,t}) + ((1 - \alpha) \mu_Y - (1 - \alpha))\text{GR}(N_{Y,t})$$

$$+ (\alpha_X \phi_X + (1 - \alpha) \mu_Y \phi_Y)\text{GR}(K_t) - (\alpha_X \phi_X + (1 - \alpha) \mu_Y \phi_Y)\text{GR}(\bar{N}_t)$$
\[ \text{GR}(Y_{t}) = \text{GR}(b_{t}) + \left((\alpha \mu_{X} - \alpha) \text{GR}(N_{X,t}) + ((1 - \alpha) \mu_{Y} + \alpha)\right)\text{GR}(N_{Y,t}) \]
\[ + (\alpha \mu_{X} \phi_{X} + (1 - \alpha) \mu_{Y} \phi_{Y})\text{GR}(K_{t}) - (\alpha \mu_{X} \phi_{X} + (1 - \alpha) \mu_{Y} \phi_{Y})\text{GR}(\bar{N}_{t}) \]
\[ - \alpha \mu_{X}(1 - \phi_{X})\kappa [N_{X,t+1}^\frac{1}{3} - N_{X,t}^\frac{1}{3}] - (1 - \alpha) \mu_{Y}(1 - \phi_{Y})\kappa [N_{Y,t+1}^\frac{1}{3} - N_{Y,t}^\frac{1}{3}] . \]

These growth equations may be rewritten in terms of the difference between the growth rate of an individual city from that of the average city.

A number of remarks are in order in taking these equations to the data. First, the assumptions of the model imply that the term GR(\bar{\Xi}_{t}) in the RHS of (28) may be treated as a total factor productivity growth rate, i.e., a Solow residual. Furthermore, it is not city-specific. Second, since the growth rate of the economy’s aggregate physical capital, term GR(\bar{K}_{t}), is also common to all cities, it could be instrumented by means of the national nominal interest rate. Third, the coefficient of the aggregate population growth rate, \((\alpha \mu_{X} \phi_{X} + (1 - \alpha) \mu_{Y} \phi_{Y})\), is the same as that of growth rate of the economy’s aggregate physical capital. Therefore, by following our approach above and expressing growth in income per person relative to the economy’s average, where as before for a city of type X the terms associated with cities of type Y serve as proxies for the average economy, the only remaining of the growth rate terms is the growth rate of a city’s population relative to the national average. The other remaining terms express the evolution of a city’s spatial complexity, relative to the economy’s average. It is these predictions that we take to the data.

### 3.2.4 Growth of Autarkic Cities

The growth equations obtained above, (28) and (29), follow from the assumption of national economic integration and specialization. To see this we may contrast with growth in autarkic cities. Working from Eq. (9.15), Ioannides (2013), p. 414, we have that the growth rate of income per person may be expressed in terms of the same (log)linear combination of the TFP growth rates of the city’s different industries, \(\alpha \ln \bar{X}_{t} + (1 - \alpha) \ln \bar{X}_{t} \), and in addition, the growth rate of the respective effective labor supply, and of the aggregate physical capital.
in that city. That is:

$$\text{GR}(Y_{\text{aut},jt}) = \alpha \text{GR}_{t,t+1}(\Xi_X) + (1 - \alpha) \text{GR}_{t,t+1}(\Xi_Y) + (\mu \phi + \nu) \text{GR}_{t,t+1}(K_{j,t})$$

$$+ (\mu(1 - \phi) - \nu) \text{GR}_{t,t+1}(H_c(N_{jt})).$$  \hspace{1cm} (30)

We note that this result predicts that other than the presence of a linear combination of the TFP growth rates of the city’s different industries the coefficient of the remaining term, $\text{GR}_{t,t+1}(H_c(N_t))$ the city’s effective population growth rate, is predicted to be positive. See Ioannides (2013), p.417. We note that whereas in Eq. (28) and (29), $K_t$ denotes aggregate physical capital in the economy, here $K_{j,t}$ denotes physical capital for city $j$ at time $t$.

The urban system of a modern market economy contains cities of different types (Ioannides (2013), Ch. 7) which are in varying degrees integrated into the national and the international economy. Therefore, city growth rates could in general be described by (28), with (30) allowing development of over-identifying restrictions. Comparing city output growth for cities engaged in intercity trade, (28), with that for autarkic cities, (30) suggests that modeling specifically cities’ trading outside the system of cities with the rest of the world, is likely to yield expressions for the determination of city GDP that differ from those where there is no international trade. Appendix B details a modification of the model to account for international trade along with intercity trade.

### 3.3 Consequences for Growth Regressions

The spatial equilibrium condition, which expresses arbitrage, turns out to have major implications for urban growth equations in the context of economic integration. This follows from a comparison between the growth equation for autarkic cities with no free movement of labor, which is derived here from from Ioannides (2013), Eq. (9.15), as Eq. (30), with the respective one for cities engaged in intercity trade, Eq. (28), and the one for cities engaged in intercity and international trade, Eq. (37).

The consequences of spatial equilibrium for urban growth regression has 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 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.

However, to the best of our knowledge, no previous literature has dealt explicitly with international along with intercity trade. The theory outlined here predicts structural differences in growth regressions across cities with different roles in the urban system. This would be critical if we were to perform a classic Solow residual analysis by working from city output in terms of factor inputs, a point forcefully made by Hsieh and Moretti (2017). It is clear from (22) that a portion of the contribution of capital and that of labor in its entirety are subsumed in the auxiliary variables \( (X_t, Y_t) \), defined in (23) and (23) above. This is also confirmed by contrasting with (30), the expression for the growth rate of autarkic cities. In work currently in progress, we plan to estimate the growth equations by also including data on capital accumulation.

Another question that would require a modification of the growth model would be to consider how anticipated growth rates on housing prices may hamper city growth. Because of varying housing supply restrictions across various US cities, Glaeser and Gyourko (2017) argue that the local and state control of land use regulations may be quite important in this regard and may also be responsible for spatial variation in housing equity accumulation by US households. Doherty (2017) dramatizes this point by invoking Hsieh and Moretti (2017), arguing that local land-use regulations reduce the United States’ GDP by as much as $1.5 trillion a year, or about 10%. As we discuss in section 6.2, our model and estimation results are consistent with the arguments proposed Glaeser and Gyourko and Hsieh and Moretti.
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 intercity and international trade, on the one hand, and the local housing market, on the other. We describe these data to provide an overall view of the empirical resources we bring to our approach.

The following major sources of data are available to us. We combine some of these into a dataset for 78 cities for the years 2002, 2007, and 2012 (an unbalanced panel), for estimation of the GDP determination equation 14. We develop a separate dataset for 96 cities annually for a 10 year period, for estimation of the house price growth equation 21. Finally, we combine data for 367 MSAs, split into small versus large cities, over a 5 year period, to estimate the GDP growth equations 28 and 29. Specifically:

- Equation 14: Data from various sources merged, for 78 cities, 2002, 2007, 2012 (an unbalanced panel). Data on city-level domestic shipments for 2002, 2007, 2012 for 78 cities are from the Commodity Flows Survey, BTS. We impute transfers via an procedure based on equation (7), as the residual of land and labor income, which we need to instrument in estimating GDP determination. Labor income is derived from BEA data; land income is based on equation (6), i.e., the product of commuting costs, wages, and square root of employment; these data are from BEA. Annual international exports by 377 MSAs, 2003-2012, from Brookings for: agriculture; educational services, medical services and tourism; engineering; finance; general business; IT; manufacturing and mining. Aggregate to obtain total MSA exports, and then merged into the 78 city definitions. The following instruments are used for estimating the IV models in equation 14: Domestic Shipments Instruments are based on the planned highway rays, lagged 30 years (Baum-Snow, 2007), defined as the number of highway segments that pass into and/or out of a central city; 30 year lagged miles of completed highway miles (both from Baum-Snow, 2007); and the difference between national population and city population from the Census Bureau. Transfers are instrumented with real unemployment receipts per capita (as in Gruber, 1997), with data obtained from BEA.
For international exports, we assume demand for exports exogenous to a city (i.e., city is small with respect to the rest of the world).

- For Equation 21: Data for 96 cities for 10 years (2003-2012), are obtained by merging the following: House prices, 1996-2013, 363 MSAs, from the FHFA; given limited geographical detail in the CPI data we use regional data for the four Census regions annually, from BLS. There are MSA-level data for 26 MSAs, annually, but to preserve a larger sample, we use regional data, and we assume these regional prices exogenous to a particular city. Similarly, all urban cities CPI is exogenous to a particular city. MSA-level GDP data, and MSA employment data, are obtained from BEA. Regarding instruments for equation 21, for the MSA employment data we utilize Saiz–Wharton data (house supply elasticity, unavailable land, Wharton regulation index), and MSA population, \( \sim 250 \) MSAs (Saiz, 2010). Instruments for MSA GDP growth minus national GDP growth are given as difference in MSA cancer deaths growth and national cancer deaths growth, 2003-2012, 96 MSAs, from the Centers for Disease Control.

- Equations 28 (large cities) and 29 (small cities), 180 and 187 MSAs, respectively, annual data for 2006-2010: The variables in these equations include MSA-level GDP (from BEA), state-level TFP (from Yamarick), MSA Employment net of commuting time (calculated from BEA data), federal funds rate (for large cities; from Federal Reserve); state-level manufacturing capital stock (for small cities; derived from investment data from Census Bureau’s ASM Geographical Area Series), highway capital stock (for small cities; derived from investment data from Census Bureau’s State Government Finances). We also include year and region fixed effects in these equations.

4.1 International versus Intercity Trade Flows

Here we discuss some features of intercity shipments data for 2002, 2007 and 2012, using the 76 city definitions we generate from the 2002 CFS. We have matched the roughly 377 MSAs with exports data from the Brookings data source. Exports from city \( j \) to the rest
of the world are obtained from the Brookings Institution\textsuperscript{15}. Since there are fewer cities in the CFS than in the Brookings dataset, many of the exporting MSAs have been combined manually in several instances into a number of broader CFS city definitions. This process was tedious and runs into the difficulty of changing MSA definitions and different numbers of MSAs across the different waves of the data. Because of these issues, we have approximately 76 cities that we are able to use from the CFS, and we match the data from the 2007 and 2012 CFS, with the MSA GDP and exports data, to roughly 76 city definitions in the 2002 CFS.

We note that the ratio of MSA international exports, defined as international shipments, to domestic exports shipments is generally highest in coastal cities, and lower in inland cities. This of course accords with intuition, given that, in general, water shipping is less costly than other modes. Washington DC is an outlier, because apparently it ships very little domestically (the government services it produces are not tradeable), and also because it has approximately 27\% of the educational services, medical services, and tourism industry exports. While it is possible to break down the exports by reported industry, it is not easy to do so for domestic shipments due to sparseness of the data in some locations that caused the Census Bureau not to disclose the data.

The comparison of the ratio of exports to domestic shipments across the three different years is interesting. For 2007, the mean value of the ratio is 0.2047 and its standard deviation 0.7704. These values imply a coefficient of variation of 3.76. In contrast, both mean and standard deviation are at 0.2738 and 1.2421, respectively, greater for 2012. However, the coefficient of variation at 4.5357 is also greater, and the range of values has widened. In other words, it appears as if U.S. cities on average have become more international export driven over time. There is also a greater spread in cities’ export ratio. Some have become much more export intensive while others have become much less export intensive, where the shift is somewhat greater on the higher end of the distribution.

\textsuperscript{15}http://www.brookings.edu/research/interactives/2015/export-monitor#10420
4.2 Descriptive Statistics

Table 1a presents descriptive stats for the data used in the regressions for equations 7 an 12. In Table 1a, the average GDP per job is approximately $47,900, with the average transfer equal to about $117,000 and the average domestic sales per job approximately $59,000. In Table 1b, during the period 2002-2012, the average annual land rent growth per job is negative for both the MSA level and the overall urban total, with the MSA level being more negative than the overall. This negative average may be attributable to the Great Financial Crisis that began in late 2007. The GDP growth rate is approximately 3.7% annually during this period of 2002-2012, while the CPI growth rate is approximately 2.3%. In Table 1c, the average annual MSA-level GDP growth rate per job in the years 2003-2012 was about 3.57%, while the average cancer death rate per job was 0.43%. Finally, in Table 1d, the average MSA nominal GDP was approximately $66.6 billion, with 537,000 "effective" jobs in "large" cities and 61,000 "effective" jobs in "small" cities.

5 Estimations

For the determination of city GDP, eq. (14), we use per-capita sales data by each city to other domestic cities, which are available for 3 years (2002, 2007, and 2012), from the Bureau of Transportation Statistics’ CFS. We first estimate eq. (14), using as the dependent variable GDP per employee in city \( j \). We also generate the ratio of exports to number of jobs (or per capita) by city \( j \) to the rest of the world. Sales by city \( j \) to other domestic cities, is normalized by the number of jobs in city \( j \). One advantage of this Brookings database is that the exports data are defined in terms of the location of production, rather than on the origin of shipment. Otherwise, the GDP for port cities with a lot of transshipments would be exaggerated.

The data for transfer payments per job in city \( j \), which is a regressor in eq. (14), are obtained by solving eq. (7) for transfers per job in terms of GDP per job, land income per land parcel, and labor income per job. Land value data at the MSA level for 46 MSA’s
are available from the Lincoln Institute of Land Policy.\textsuperscript{16} However, to broaden our sample we utilize Eq. (6) to develop land value estimates, which is explained in the data section above. We have matched our derived land value MSA-level data with data on unemployment insurance receipts, completed highway miles and per-capita highway “rays” per MSA, and the exports and shipments data. These data are used to estimate the GDP determination equation with an Instrumental Variables procedure. Cities that ship more goods domestically are expected to rely heavily on the national highway network, which was developed many years ago. For this reason, the size of the highway network outside of a particular city is used as an instrument for domestic shipments; a larger national network outside the city should lead to higher domestic shipments. We use highway rays per-capita as another instrument for domestic shipments, to represent the congestion and/or roads quality within each city. National population relative to local (i.e., city) population is an instrument that controls for the demand for a city’s out-of-city shipments. For the transfers variable, Gruber (1997) utilized unemployment insurance claims as an instrument for transfers, and we follow that approach here. Finally, the demand for a city’s international exports is considered exogenous, given that a city is small relative to the rest of the world.

As we discuss above, GDP for different cities are determined simultaneously, which is to say that their key components are determined simultaneously. Exports other cities make to a particular city reflect their own economic activity, because they themselves import from other cities. In order to select instruments, we recognize that economic activity in each city 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.\textsuperscript{17} The complex dependence of income per person on city geography,

\begin{footnotesize}
\textsuperscript{16}See Davis and Palumbo (2006), Davis and Heathcote (2007), and http://www.lincolninst.edu/subcenters/land-values/metro-area-land-prices.asp
\textsuperscript{17}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
\end{footnotesize}
according to eq. (8), serves to underscore the welfare costs of congestion.

The spatial equilibrium, Eq. (24), dictates our choice of variables in the empirical analysis. For the estimation of eq. (15), we work with the difference of two terms. The first term is the difference between the housing price growth rate in city \( j \) and the national housing price growth rate. The second independent variable is difference between the GDP growth rate per job in city \( j \) and the GDP growth rate per job in all MSA’s. The city-level growth rate uses the MSA-level GDP and employment data from Telestrian, and the national growth rate is based on the sum of GDP in all 96 MSA’s, and the sum of the jobs in all 96 MSA’s. The first independent variable in eq. (15) is the difference between the growth rate in city \( j \)’s Consumer Price Index (CPI) and the growth rate in the national urban CPI. Both of these CPI estimates were obtained from the U.S. Bureau of Labor Statistics,\(^{18}\) for the years 2002-2012. There are only 26 MSA’s for which BLS reports CPI data, and this is why we use the regional CPI measures (and these 4 regions encompass all MSAs in the entire US). Finally, we include two additional covariates — one involving employment per capita in an MSA, and another with the national employment per capita. We include region and year fixed effects. Given that GDP growth is endogenous, we use the following instruments in an Instrumental Variables estimation procedure: the difference between MSA per capital cancer death growth rates and national per capital MSA growth rates; the share of undevelopable land area in the MSA; the land supply elasticity; and the Wharton Residential Land Use Regulation Index.

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.

\(^{18}\)http://www.bls.gov/cpi/cpifact8.htm
6 Regressions

We report here estimation results with the three key equations obtained from our theoretical model. First is the condition defining the determination of city GDP, Eq. (14) but only for the 76 MSA’s for which we have sufficient data, for the years 2002, 2007, and 2012; see Table 2. Second is the spatial equilibrium condition, annually for the years 2002 through 2012, in terms of housing prices, Eq. (21), reported in Table 4. The estimation of urban GDP determination requires information on domestic demand, which is proxied by domestic shipments from city \( j \) to all cities, the availability of which is limited to those 3 years. We ”deflate” the data in this estimation equation with a deflator obtained from the ratio of nominal to real GDP. Third, we report estimation results along the lines of the specific predictions of the growth model, Eq. (28), for the one-half of the sample of cities with larger GDP, (29), for the one-half of the sample of cities with lower GDP, (30), and for all cities; see Table 6. The split-sample estimations are motivated by the trading cities model, Eq. (28) and (29).

6.1 Determination of MSA GDP Regressions

Our estimation results for Eq. (14) are shown in Table 2. For the domestic shipments variable, in addition to the number of highway “rays planned” per capita, and the share of national population that is outside of the particular city, we use the following as instruments [ Baum-Snow (2007)]:

- For the 2002 observations, the share of national completed miles outside of the city, of highways in 1960 passing through all central cities that were in the original plan;
- For the 2007 observations, the share of national completed miles outside of the city, of highways in 1975 passing through all central cities that were in the original plan;
- For the 2012 observations, the share of national completed miles outside of the city, of highways in 1990 passing through all central cities that were in the original plan.
According to Baum-Snow (2007), which pioneered the use of these instruments, a ray is a highway segment that connects to the central city. If a highway segment passes through a central city (into and out of the city only once), it counts as 2 rays. We normalize this rays variable by the population of the city (which varies over time), to obtain our instrument. This normalization is crucial to distinguish between cities with a lot of extra highway capacity versus those that are congested over time relative to the number of people and firms likely using the roads. Note also that the “original plan” for highways was developed in 1947. The lagged national share of completed highways miles outside of a given city will vary across different cities, because this measure excludes the particular city, in order to estimate the effect of the highway network in the rest of the nation on a particular city’s shipments.

We argue that these highway instruments are highly correlated with domestic shipments (which we have confirmed empirically). But they are 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 the 1940’s). Shocks to GDP between 22 and 42 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.

Table 2 reports OLS and instrumental variable estimation results in columns 1– and 7–12, respectively, covering 76 MSA’s for which we have suitable data, using Eq. (14), annually for 2002, 2007, and 2012. We put all variables into real terms by using a price deflator that we generate by using the ratio of nominal GDP to real GDP for each city. This is particularly important because the years in our analysis were 2002, 2007, and 2012, which included some boom years and the Great Recession (12:2007–06:2009). In all specifications,
the dependent variable is real GDP per job. The independent variables either real domestic shipments (domestic sales) to other cities per job and exports to the ROW, or those variables and in addition real transfers per job (for which we appeal to Gruber (1997) and use the Unemployment Insurance claims data as an instrument for transfers). We have greater confidence in those regressions that exclude transfers, as that variable is computed, rather than measured. Fits as measured by $R^2$ vary, but for OLS with fixed effects (FE) and IV with FE are 0.822 and 0.805, respectively. are positive and highly significant with the IV estimator. All of the estimated coefficients are positive as predicted by the theory. Except for OLS specifications reported in Columns 1, 2 and 3, all other regressions do not yield statistically significant coefficients for transfers. In all IV specification the P-value for the J-Statistic is greater than 0.05, implying the overidentification restrictions are valid. We note, however, that the correct variable in Eq. (14) should be net exports, but we lack reliable city-level data on international imports. In an important sense, the reality of modern manufacturing implies that exports and imports are highly correlated, and in this sense exports proxy to some extent for imports. Please see the notes on the bottom of T. 2 for further details on the estimations.

6.2 Spatial Equilibrium Regressions

We report estimations along the lines of the implications of spatial equilibrium, first in terms of land prices, Eq. (15) as shown in Table 3, and second in terms of housing prices, Eq. (21), shown in Table 4. We report estimation results with region fixed effects instead of MSA fixed effects and year fixed effects or a year time trend. We normalize by the number of jobs instead of population and also include the two “spatial complexity” terms at the end of Eq. (21). Recall that the spatial equilibrium condition predicts that $S^{-1}\beta^{-1}$ is the coefficient of the term that expresses the difference of a city’s GDP growth per capita relative to that of the national average, and $S^{-1}\beta^{-1} > 1$.

Specifically, In Table 4, when we use OLS with region and year fixed effects, the estimated coefficient for $S^{-1}\beta^{-1}$ is statistically significant but implausible, since it is less than 1. The
coefficient on CPI difference is positive but insignificant. But the $S^{-1} \beta^{-1}$ being less than 1 result is implausible, perhaps because the estimate is biased due to omitted variables and/or endogeneity concerns.

Next we estimate the model using instrumental variables, using as instruments the difference between the per job cancer death growth rates at the MSA level and the GDP growth rate at the national level (since the national GDP should be exogenous to an MSA); second, land area that is unavailable for housing; third, the housing supply elasticity; and fourth, the Wharton Regulation Index. We perform the estimations with fixed effects at the region level, and time effects. The results are as follows. The estimates of the key parameters, the coefficients of the regional CPI growth rate minus that of the urban CPI growth rate and of the difference of the MSA GDP per capita growth rate minus the national one, generally agree with the predictions. The estimate of $S^{-1} \beta^{-1}$ is at 4.49 greater than 1, as predicted, and significant, and the $J-$statistic is small ($P-$value=0.1514); the coefficient on the difference of the CPI terms is as predicted negative but significant at 7%. If, however, we follow the theory and adopt an one-sided test ($P-$value=0.0385), and the estimate is significant at 5%. A quick calculation shows that the implied parameters are not outrageously implausible. The implied value of $S,$ the savings rate, is about 0.40 and that of $\beta,$ the elasticity of housing in the utility function, is about 0.56. Both these estimates are too large, though not outside the bounds for those parameters. Specifically, BLS reports\textsuperscript{19} that the share of housing in expenditure for urban households was 34.2\% in 2011.

Therefore, we are tempted to conclude that the latter instrumental variables specification with region and year fixed effects is the “preferred” one which controls for endogeneity and omitted variables (through fixed effects). They give us the desired sign, magnitude, and significance on the estimate of $\frac{1}{S^2}$, and the desired sign, magnitude, though not significance of $S^{-1} \beta^{-1}$. The CPI difference term is insignificant; and the $J-$statistic implies the overidentification restrictions are valid since the $P-$value is much greater than 0.05 so using conventional levels of significance we can reasonably conclude this is the case. Arguably, we can justify using the region fixed effects instead of the MSA fixed effects, since the regional

level also preserves degrees of freedom with only 4 regions instead of 97. Also, for consistency it makes sense to use the same level of aggregation for the fixed effects as we have for the CPI regions.

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 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.

6.3 GDP Growth Rate Regressions

Finally, we report estimations along the lines of the specific predictions of the growth model; see Table 5. Eq. (28) is set in terms of integrated cities of “one type” and (29) is set in terms of integrated cities of the “other type.” We estimate the former for the roughly one-half of the sample of cities with GDP above the median, and the latter for the approximately one-half of the sample of cities with GDP below the median. Our theory predicts that the GDP growth equations for integrated cities depend on the growth rate of total factor productivity (TFP) for integrated cities, on its own population growth rate and on that of the other city types and on the national urban population growth rate, on the growth rate of aggregate physical capital in the economy (in terms of which each city’s own capital accumulation growth rate is expressed via the model), and on the growth rates of spatial complexity terms for each city type. Interestingly, the model predicts TFP growth rates are the same multiplicative functions of the TFP growth rates of the representative industries in the economy and differ between integrated and autarkic cities by a positive constant. Having experimented with state-level TFP growth rates,\textsuperscript{20} we have chosen to report results with metro-area based TFP

\textsuperscript{20}We are grateful to Roberto Cardarelli and Lusine Lusinyan for lending us their data on metro-level TFP estimates. See Cardarelli and Lusinyan (2015).
growth rates.\footnote{We are grateful to Morris Davis for lending us his data on metro-level TFP estimates. We are aware of only two other studies in the literature that involve US metro-area TFP growth rates; these are Hsieh and Moretti (2017) and Hornbeck and Moretti (2015). However, their TFP growth rate computations are not made public as of the time of writing.}

We find that for the most part, the signs of the coefficient estimates on these variables are consistent with our expectations, and many of them are statistically significant. Also, the theory accounts for the dependence of the time costs of commuting on city size. We eschew a very tight parametrization on account of commuting costs and we adjust the number of jobs in each city as follows. The effective number of jobs, $H_c(N_{jt})$, defined in (4) above, is defined as follows by using the reported metro-area specific average daily commuting time in minutes, average commute time $jt$:

$$H_{eff,jt} = \text{total jobs} \times \frac{1800 - 5 \times 52 \times \text{average commute time}_{jt}/60}{1800}.$$ 

Regarding TFP growth rates, which enter the GDP growth equations, the best that we can do is to proxy them by means of state-level TFP growth rates. Similarly, in the absence of city-specific physical capital, we use state-level physical private capital and state-level public capital, as measured by investment in state highways.\footnote{The private capital data come from the US Census Annual Survey of Manufactures, geographic area series. The public capital data come from the US Census State Government Finances data series. The data recoding and processing is our own.}

Splitting the sample into large- vs. low-GDP cities is motivated by the commonly obtained prediction of new geography-style of international trade that more highly-integrated cities are more productive. At the same time, larger cities on the one hand may be less likely to specialize and to depend on international trade, while on the other hand they may be more likely to export products. We use the growth rate in the federal funds interest rate to proxy for the growth rate of aggregate physical capital in equations (28) and (29), in accordance with our theory. Table 5 reports estimation results with four different regressions. The TFP growth rates have positive and highly statistically significant coefficients in all four regressions. Columns 1 and 2 report estimations for large and small cities, respectively.
Table 5 shows that the own average net employment growth rate has a significant and positive (as predicted) coefficient, and that for the other city type negative (as predicted). The coefficient of the national net employment growth rate is negative (as predicted) and significant in both regressions reported on columns 1 and 2. The coefficient of the growth rate of the federal funds rate is statistically significant but positive, in contrast to our theory. Our theory suggests that the growth rate of less integrated cities, which we identify with smaller cities, depends on the growth rate of their own physical capital. In the absence of data on each city’s physical capital, we include the growth rates for private capital and for highway capital at the state level. Column 2 shows that the coefficients for both those variables are positive, as predicted, but only that of private capital is statistically significant. Columns 3 and 4 report regressions with all cities. Column 3 reports regression results when all explanatory variables are included, except for the national net employment growth rate, and Column 4 reports results when in addition the growth rates for the state-level private and highways capital stocks are also excluded. Interestingly, the coefficient of the growth rate of the federal funds rate is negative (as predicted) and statistically significant. The overall fit is quite good for both regressions, with $R^2$’s being quite high at 0.6315 and 0.5697, for large and small cities, respectively, and at 0.5926 and 0.5828 for the all cities regressions reported on Columns 3 and 4.

6.4 Diagnostics with Simulations

We employ numerical simulation using the coefficient estimates to examine how a shock (separately) in the value of a city’s international exports, domestic shipments, and transfers impacts the city’s house price growth relative to the national average (taking the national average as given). Starting with international exports, we examine how a 10% shock affects the city’s own GDP (per person, in real terms), based on the coefficient estimates for eq. (14) Then, we convert this city-level real GDP per person into nominal GDP per job, and determine the new growth rate in the city’s nominal GDP per job (to make everything compatible with the variables in eq. (21). Finally, we examine how this change in the city’s growth rate of nominal GDP per job is transmitted to the city’s house price growth relative
to the national average house price growth. We perform such simulation exercises separately for a shock to international exports, domestic shipments, and transfers, for a set of 43 cities for which the city definitions are consistent in both equations (14) and (21). The results, reported in Figures 1, 2, and 3, for each city show the change in local relative to national house price growth, based on the fitted value of house price growth in eq. (21) using 2012 actual GDP growth data for the initial point in the graph. The second point in the graph is the fitted value from (21), using the GDP growth rate based on the shock to GDP in eq. (14). We also report confidence bands in these graphs (of $+/ - 2$ standard deviations), as the dotted lines.

The results imply that a shock to exports leads to an increase in house price growth relative to the national average in all cities in our sample (except for New Orleans). Also, the effect of the shock is quite dramatic in most cases. In contrast, a shock to domestic shipments and to transfers leads to more mixed results: some cities experience flat growth, others slightly lower growth, and some slightly positive growth. The shock in our simulations is a one-time, transitory shock. Therefore, residents in some cities may not regard such a transitory shock as sufficient to lead to a permanent change in their income to warrant purchasing a house, and therefore there is less impact on housing markets (and price growth). Perhaps in the case of transfers, residents receive increased unemployment payments when they lose their primary source of employment income, and for this reason, the results on the housing market are much more mixed. Thus, it is interesting that a transitory shock to exports has a relatively large and almost universally positive impact on the housing markets. In this case, perhaps there is less crowding out of GDP that occurs when exports increase, relative to an increase in domestic shipments, and therefore this may explain why there is such a relatively dramatic effect on the housing markets in response to a transitory shock to exports.
7 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 and international trade to its growth rate performance. We estimate the GDP determination equation, a spatial equilibrium equation, and two sets of growth rate regressions. Our primary empirical findings confirm the comparative statics implications of our theoretical model. In several cases, such as in the spatial equilibrium equation, we have controlled for endogeneity with an Instrumental Variables (IV) approach. One of the unique facets of our work is analogous to Autor, Dorn and Hanson (2013). They examine how imports from China affect the labor markets in U.S. "commuting zones". Our efforts have the potential to shed some light on transmission of labor market shocks on goods markets in trading cities. In turn, we then demonstrate through a parallel empirical analysis that changes to the city-level goods markets affect local housing prices. In other words, our findings imply that trading cities’ labor market shocks can indirectly impact the housing markets through the goods markets, and these effects can vary depending on whether the trading cities are "large" or "small".

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, like New York, San Francisco, Vancouver, London, Singapore, Hong Kong, etc. In those cities and many others, it is not only international 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.
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doi:10.1093/restud/rdt039


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9 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 elasticities \( 1 - \phi_J \), and \( \phi_J \), 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, \( \Xi_{Jt} \). Production conditions for each of two industries \( J \) are specified via their respective total cost functions:

\[
B_{jt}(Q_{jt}) = \left[ \frac{1}{\Xi_{jt}} \left( \frac{W_t}{1 - \phi_J} \right)^{1-\phi_J} \left( \frac{R_t}{\phi_J} \right)^{\phi_J} \right]^{u_J} \left[ \sum_m P_{zt}(m)^{1-\sigma} \right]^{1-u_J} Q_{jt}, \tag{31}
\]

where \( Q_{jt} \) is the total output of good \( J = X, Y \), \( P_{zt} \) is the price of the typical intermediate, elasticity parameters \( u_J, \phi_J \) satisfy \( 0 < u_J, \phi_J < 1 \), and the elasticity of substitution in the intermediates composite \( \sigma \) is greater than 1. The TFP term \( \Xi_{jt} \), 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, \( \phi_J \) and \( 1 - \phi_J \), \( J = X, Y \), respectively.\(^{23}\) The respective total cost function is

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

\(^{23}\)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 \( \int_0^{M_{it}} \rho_{it}^{1-\epsilon_t} \) on the r.h.s. of the cost function \( b_{it}(Z_{jt}) \).
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 \( \frac{\sigma}{\sigma - 1} \):

\[
P_{Z,J,t} = \frac{\sigma}{\sigma - 1} \left( \frac{W_t}{1 - \phi_J} \right)^{1-\phi_J} \left( \frac{R_t}{\phi_J} \right)^{\phi_J}.
\]

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

10 Appendix B (Not for Publication): Derivations of City GDP for the Urban System with International Trade

We proceed to modify the model of the urban system by postulating that while cities specialize, some of the cities export to, while other import from, the international economy. We modify the urban structure as follows. There are \( n_X \) cities that specialize in the production of good \( X \) and sell all of their output within the domestic economy producing \( Q_X \) each; there are \( n_{X,x} \) cities each with population \( N_{X,x} \) also specializing in the production of good \( X \) that in addition export \( Q_{X,ex} \) of their output, producing in total \( Q_{X,p} \) each. Similarly, there are \( n_Y \) cities that specialize in the production of good \( Y \) and sell all of their output \( Q_Y \) in the domestic economy; and there are \( n_{Y,m} \) cities each with population \( N_{Y,m} \) specializing in the production of good \( Y \), producing \( Y \) in quantity \( Q_{Y,p} \) each, which also import \( Q_{Y,im} \). We simplify the derivations by assuming that the quantities of imports and exports are given.

The national population is distributed over all cities, as before:

\[
n_X N_X + n_{X,x} N_{X,x} + n_Y N_Y + n_{Y,m} N_{Y,m} = N. \tag{32}
\]

Similarly, total capital is allocated to all cities:

\[
n_X K_X + n_{X,x} K_{X,x} + n_Y K_Y + n_{Y,m} K_{Y,m} = K. \tag{33}
\]
International trade balance requires that the value of the national exports of good X equal the value of the national imports of good Y:

\[ n_{X,x} P_X Q_{X,ex} = n_{Y,m} P_Y Q_{Y,im}. \]  

(34)

Domestic trade balance requires that spending by all X cities on good Y equal spending on good X by all Y cities:

\[ (1 - \alpha)n_X P_X Q_X + (1 - \alpha)n_{X,x} P_{X,p} = \alpha n_Y N_Y P_X + \alpha n_{Y,m} N_{Y,m} Q_{Y,p}. \]  

(35)

These conditions along with the conditions for spatial equilibrium and capital market equilibrium across cities of all types allows us to solve for capital allocation and thus for the output by different types of cities, given city populations and numbers by type. A tedious set of derivations (see Appendix) yields the capital allocations to different city types, as fractions of the aggregate capital, with the factors of proportionality being functions of city sizes and numbers and of parameters.

Thus, using the expressions from the Appendix in (44) we obtain expressions for output for each city type X, Y. The counterparts for city types X, x and Y, m, respectively those that export good X and import good Y, are:

\[ Q_{X,x} = \Xi_{X,x} H_{X,x}^{\mu_X (1 - \phi_X)} K_{X,x}^{\mu_X \phi_X}, \quad Q_{Y,m} = \Xi_{Y,m} H_{Y,m}^{\mu_Y (1 - \phi_Y)} K_{Y,m}^{\mu_Y \phi_Y}, \]  

(36)

. The corresponding growth rates for city output of each type are obtained by taking logs and first-differencing. That is,

\[ \text{GR}(Q_{X,x,t}) = \text{GR}(\Xi_{X,t}) + \mu_X \phi_X [\text{GR}(FPK_{X,t}) + \text{GR}(K_t)] + \mu_X (1 - \phi_X) \text{GR}(H_{X,x,t}), \]  

(37)

where \( \text{GR}(FPK_{X,t}) \) denotes the factor of proportionality in the expression for \( K_{X,t} \), and \( H_{c,X,x,t} \) is given by (4), for \( N_{X,x}(t) \). An expression similar to (37) is obtained for \( \text{GR}(Q_{Y,m,t}) = \ln Q_{Y,m,t+1} - \ln Q_{Y,m,t} \).

This model is formulated in terms of two different tradeable goods, which are traded domestically and internationally and are used in each city to produce a non-tradeable good that is used for consumption and investment. The model may be generalized, following
Ventura (2005) to the case of many goods. The simplified two-good case makes it clear
that the output growth rates for different city types are described by structurally different
expressions, that is for autarkic cities, for cities that trade domestically and for cities that
export or import internationally.

For the cities that neither export nor import internationally, conditions (9.29–9.31) in
Ioannides, op. cit., that follow from the assumptions of capital mobility and spatial equilib-
rium continue to hold. In addition, the counterpart of (9.29) for cities of type $X$ and $X_{ex}$
yields the counterpart of (9.30), which is implied by spatial equilibrium:

\[ \frac{P_X Q_X}{P_X Q_{X,p}} = \frac{N_X}{N_{X,x}}. \]  

(38)

And similarly for cities of type $Y$ and $Y_{im}$:

\[ \frac{P_Y Q_Y}{P_Y Q_{Y,p}} = \frac{N_Y}{N_{Y,m}}. \]  

(39)

In other words, the relative share of output by cities of type $X, Y$ are proportional to their
respective relative populations. Free capital mobility between $X, Y$ cities implies condition
(9.31) in Ioannides, op. cit.,

\[ \frac{K_X}{K_Y} = \frac{N_X \phi_X (1 - \phi_Y)}{N_Y \phi_Y (1 - \phi_X)}, \]

(40)

and between $X$-type cities and $X$ type exporting cities

\[ \frac{K_{X,x}}{K_X} = \frac{N_{X,x}}{N_X}, \]

(41)

and between $Y$-type cities and $Y$ type importing cities

\[ \frac{K_{Y,m}}{K_Y} = \frac{N_{Y,m}}{N_Y}. \]

(42)

These intermediate results will be critical in our derivation of expressions for city output in
the presence of international trade.

In each city output of the composite good, which is not traded but is used for consumption
and investment is produced by using quantities of tradeable goods $X, Y$ according to

\[ Q_X = Q_X^\alpha Q_Y^{1-\alpha}. \]
The corresponding (natural) price index is:

\[ P \equiv \left( \frac{P_X}{\alpha} \right)^{\alpha} \left( \frac{P_Y}{1 - \alpha} \right)^{1 - \alpha}, \]

which can be normalized and set equal to 1.

The objective of the analysis is to write expressions for real output of different city types, given total capital and total labor in the economy, \((K, N)\), and given the sizes of different city types, \((N_X, N_{X,x}, N_Y, N_{Y,m})\). For example, the real income of a city of type \(X\) is \(P_X Q_X\), which by using the normalization condition and the spatial equilibrium condition may be written as

\[ \alpha^\alpha (1 - \alpha)^{1-\alpha} Q_X^{\alpha} Q_Y^{1-\alpha} \left( \frac{N_X}{N_Y} \right)^{1-\alpha}, \tag{43} \]

where:

\[ Q_X = \tilde{\xi}_X H_X^{\mu_X(1-\phi_X)} K_X^{\mu_X \phi_X}, Q_Y = \tilde{\xi}_Y H_Y^{\mu_Y(1-\phi_Y)} K_Y^{\mu_Y \phi_Y}, \tag{44} \]

where \(\mu_X, \mu_Y\) may actually be greater or less than 1. The counterparts of these expressions follow for the other types of cities.

We proceed by using the spatial equilibrium conditions among cities of type \(X, Y\), (38) and (39), in the domestic trade balance condition (35) to eliminate \(Q_{X,p}, Q_{Y,p}\). We thus have:

\[(1 - \alpha) \left[ n_X + \frac{N_{X,x}}{N_X} \right] P_X Q_X = \alpha \left[ n_Y + n_{Y,m} \frac{N_{Y,m}}{N_Y} \right] P_Y Q_Y. \]

Solving for \(\frac{P_X Q_X}{P_Y Q_Y}\) gives:

\[ \frac{P_X Q_X}{P_Y Q_Y} = \frac{\alpha N_X n_Y N_Y + n_{Y,m} N_{Y,m}}{1 - \alpha N_Y n_X N_X + n_{X,x} N_{X,x}}. \tag{45} \]

This is a straightforward generalization of the condition in the absence of international trade: if \(n_{X,x} = n_{Y,m} = 0\), the spending on good \(Y\) by each city of type \(X\) is equal to the spending on good \(X\) by each city of type \(Y\). From the ratio of the value of output of the typical exporting to importing city follows:

\[ \frac{P_X Q_{X,p}}{P_Y Q_{Y,m}} = \frac{\alpha N_{X,x} n_Y N_Y + n_{Y,m} N_{Y,m}}{1 - \alpha N_{Y,m} n_X N_X + n_{X,x} N_{X,x}}. \tag{46} \]

Rearranging the international trade balance condition (34) gives an equation for the terms of trade:

\[ \frac{P_X}{P_Y} = \frac{n_{Y,m} Q_{Y,m}}{n_{X,x} Q_{X,ex}}. \tag{47} \]
Rewriting the labor market condition by using the spatial equilibrium conditions yields:

\[ n_X N_X + n_{X,x} N_X \frac{P_X Q_{X,p}}{P_X Q_X} + n_Y N_Y + n_{Y,m} N_Y \frac{P_Y Q_{Y,p}}{P_Y Q_Y} = N. \]

Using it along with the domestic trade balance condition as a simultaneous system of equation allows us to solve for \((n_{X,x} P_X Q_{X,p}, n_{Y,m} P_Y Q_{Y,p})\) and obtain:

\[ n_{X,x} P_X Q_{X,p} = \frac{\alpha(N - n_X N_X) - (1 - \alpha)n_X N_Y \frac{P_X Q_X}{P_Y Q_Y}}{(1 - \alpha)\frac{N_Y}{P_Y Q_Y} + \alpha \frac{N_X}{P_X Q_X}}; \quad (48) \]

\[ n_{Y,m} P_Y Q_{Y,p} = \frac{(1 - \alpha)(N - n_Y N_Y) - \alpha n_Y N_X \frac{P_Y Q_Y}{P_X Q_X}}{(1 - \alpha)\frac{N_Y}{P_Y Q_Y} + \alpha \frac{N_X}{P_X Q_X}}; \quad (49) \]

Dividing Eq. (49) by Eq. (48) and rearranging allows us to express \(\frac{n_{Y,m}}{n_{X,x}}\) in terms of \(\frac{P_X Q_X}{P_Y Q_Y}\). Then, using Eq. (47) yields an expression for the terms of trade, in terms of \(Q_{Y,im}/Q_{X,ex}\), which are given, \((n_{X,X}; n_{X,x}; n_{X,x}; n_Y; N_Y; N_{Y,m} N_{Y,m})\), and parameters:

\[
\frac{P_X}{P_Y} = \frac{Q_{Y,im} X_{N_X} (N - n_Y N_Y)(n_Y N_Y + n_{Y,m} N_{Y,m}) - n_Y N_Y (n_X N_X + n_{X,x} N_{X,x})}{n_X N_X + n_{X,x} N_{X,x} - n_X N_X (n_Y N_Y + n_{Y,m} N_{Y,m})}. \quad (50)
\]

This solution demonstrates an important role for international trade on the urban structure. It is simplified by solving next below for \(n_X N_X + n_{X,x} N_{X,x}, n_Y N_Y + n_{Y,m} N_{Y,m}\). The expressions obtained for outputs by different types of cities, namely exporting and non-exporting cities of different types differ depending upon each city type.

Working with the capital mobility conditions (40), (41), and (42) allows us to solving for the capital allocations to different city types and therefore write expressions for real output, the counterparts of (43) for city types that export \(X\) and that import \(Y\). This yields:

\[
n_X N_X + n_{X,x} N_{X,x} = \frac{\alpha(1 - \phi_X)}{\alpha(1 - \phi_X) + (1 - \alpha)(1 - \phi_Y) N; n_Y N_Y + n_{Y,m} N_{Y,m} = \frac{(1 - \alpha)(1 - \phi_Y)}{\alpha(1 - \phi_X) + (1 - \alpha)(1 - \phi_Y)} N. \quad (51)
\]

This solution in turn simplifies (50). It also simplifies (45), which becomes:

\[
\frac{P_X Q_X}{P_Y Q_Y} = \frac{1 - \phi_Y}{1 - \phi_X} \frac{N_X}{N_Y},
\]

and (46), which becomes:

\[
\frac{P_X Q_{X,p}}{P_Y Q_{Y,p}} = \frac{1 - \phi_Y}{1 - \phi_X} \frac{N_{X,x}}{N_{Y,m}}.
\]
The allocations of total capital to the different types of cities are:

\[
K_X = \frac{N_X \phi_X (1 - \phi_Y)}{n_X N_X \phi_X (1 - \phi_Y) + n_{X,x} N_{X,x} \phi_X (1 - \phi_Y) + n_Y N_Y \phi_Y (1 - \phi_X) + n_{Y,m} N_{Y,m} \phi_Y (1 - \phi_X)} K
\]

\[
K_{X,x} = \frac{N_{X,x} \phi_X (1 - \phi_Y)}{n_X N_X \phi_X (1 - \phi_Y) + n_{X,x} N_{X,x} \phi_X (1 - \phi_Y) + n_Y N_Y \phi_Y (1 - \phi_X) + n_{Y,m} N_{Y,m} \phi_Y (1 - \phi_X)} K
\]

\[
K_Y = \frac{N_Y \phi_Y (1 - \phi_X) \phi_X (1 - \phi_Y)}{n_X N_X \phi_X (1 - \phi_Y) + n_{X,x} N_{X,x} \phi_X (1 - \phi_Y) + n_Y N_Y \phi_Y (1 - \phi_X) + n_{Y,m} N_{Y,m} \phi_Y (1 - \phi_X)} K
\]

\[
K_{Y,m} = \frac{N_{Y,m} \phi_Y (1 - \phi_X)}{n_X N_X \phi_X (1 - \phi_Y) + n_{X,x} N_{X,x} \phi_X (1 - \phi_Y) + n_Y N_Y \phi_Y (1 - \phi_X) + n_{Y,m} N_{Y,m} \phi_Y (1 - \phi_X)} K
\]
11 Tables

- Table 1a, 1b, 1c, 1d, 1e: Descriptive Statistics
- Table 2: Estimation Results for City GDP determination, Eq. (14), for 76 cities, 2002, 2007, 2012
- Table 3: Estimation Results for Spatial Equilibrium, Eq. (15), 26 MSA’s, 2003-2012
- Table 4: Estimation Results for Eq. (21), 96 MSA’s, 2003–2012
- Table 5: Growth Regressions for Large and Small Cities, Equations (28), (29).
Table 1a: Descriptive Statistics for Variables in Equations 7 and 12, 76 Cities, Annual City-level data for 2002, 2007, 2012

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Std. Dev.</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commute time (min)</td>
<td>45.9</td>
<td>25.5</td>
<td>48.0</td>
<td>13.8</td>
<td>64.9</td>
<td>166</td>
</tr>
<tr>
<td>Exports per person</td>
<td>0.00403</td>
<td>0.03365</td>
<td>0.03103</td>
<td>0.00081</td>
<td>0.0352</td>
<td>166</td>
</tr>
<tr>
<td>GDP per person²</td>
<td>0.04964974</td>
<td>0.04499679</td>
<td>0.07844726</td>
<td>0.02197727</td>
<td>0.01805659</td>
<td>166</td>
</tr>
<tr>
<td>Open highway miles in plan (lagged)</td>
<td>42.40</td>
<td>25.40</td>
<td>242.00</td>
<td>0.00</td>
<td>52.78</td>
<td>166</td>
</tr>
<tr>
<td>Population</td>
<td>3094521</td>
<td>1959781</td>
<td>1983753</td>
<td>133001</td>
<td>3394605</td>
<td>166</td>
</tr>
<tr>
<td>Labor income ($)</td>
<td>21237</td>
<td>20705</td>
<td>36520</td>
<td>10708</td>
<td>4628</td>
<td>166</td>
</tr>
<tr>
<td>Land income ($)</td>
<td>3791</td>
<td>22483</td>
<td>213303</td>
<td>8637</td>
<td>4183</td>
<td>166</td>
</tr>
<tr>
<td>Highways planned (lagged)</td>
<td>20427</td>
<td>27222</td>
<td>18403</td>
<td>0</td>
<td>18620</td>
<td>162</td>
</tr>
<tr>
<td>Domestic shipments per person²</td>
<td>1371429</td>
<td>887984</td>
<td>8267733</td>
<td>52444</td>
<td>1440068</td>
<td>162</td>
</tr>
<tr>
<td>Total jobs</td>
<td>24804</td>
<td>23045</td>
<td>69680</td>
<td>10893</td>
<td>9903</td>
<td>162</td>
</tr>
<tr>
<td>Wages per person ($)</td>
<td>280</td>
<td>263</td>
<td>22798</td>
<td>-16373</td>
<td>6000</td>
<td>162</td>
</tr>
<tr>
<td>Transfers ($)</td>
<td>1715568</td>
<td>1477045</td>
<td>5002035</td>
<td>305390</td>
<td>98282</td>
<td>162</td>
</tr>
<tr>
<td>UI receipts per person (2002 $)</td>
<td>1146</td>
<td>166</td>
<td>166</td>
<td>166</td>
<td>165</td>
<td>162</td>
</tr>
</tbody>
</table>

*While we have compiled data for 100 “cities” in each of the 3 years, we present data here for 76 cities (although some have missing data for some years).

With the full sample of 100 cities, the mean of the domestic shipments per job is higher than the mean of GDP per job, because for the domestic shipments data, many of what we call “cities” include differences in jurisdiction definitions that caused difficulties when we created crosswalks for different data sources.

Therefore, we drop the some of these “cities”, leaving us with data for 76 cities that we present in this table and use for our analysis of eq 12.
Table 1b: Descriptive Statistics for Variables in Equation 13, 26 MSA’s, 2002-2012

<table>
<thead>
<tr>
<th></th>
<th>Land Value per Job</th>
<th>Land Growth per Job</th>
<th>Total Growth in GDP per Job</th>
<th>CPI Growth per Job</th>
<th>MSA Growth in All-Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.03443627</td>
<td>0.00616421</td>
<td>0.03720451</td>
<td>0.02363565</td>
<td>0.02394109</td>
</tr>
<tr>
<td>Median</td>
<td>0.0259666</td>
<td>0.0093421</td>
<td>0.03713319</td>
<td>0.0264788</td>
<td>0.026043</td>
</tr>
<tr>
<td>Max</td>
<td>0.157959</td>
<td>0.078013</td>
<td>0.05782928</td>
<td>0.05187215</td>
<td>0.036955</td>
</tr>
<tr>
<td>Min</td>
<td>-0.8518781</td>
<td>-0.205807</td>
<td>-0.07548952</td>
<td>-0.0249688</td>
<td>-0.0035778</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.2693251</td>
<td>0.1214613</td>
<td>0.01929285</td>
<td>0.0135203</td>
<td>0.01301373</td>
</tr>
</tbody>
</table>

Obs 286 260 286 260 286 286
Table 1c: Descriptive Statistics for Variables in Equation 20, 96 MSA's, 2003-2012

<table>
<thead>
<tr>
<th></th>
<th>Growth in CPI (region)</th>
<th>Growth in CPI (MSA)</th>
<th>Growth in GDP per job (MSA)</th>
<th>Growth in GDP per job (nation)</th>
<th>Jobs per capita (nation)</th>
<th>Jobs per capita (MSA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.025275982</td>
<td>0.024529681</td>
<td>0.03566983</td>
<td>0.03622301</td>
<td>0.441852852</td>
<td>0.437901623</td>
</tr>
<tr>
<td>Median</td>
<td>0.026548288</td>
<td>0.028339517</td>
<td>0.03461982</td>
<td>0.03935728</td>
<td>0.451738849</td>
<td>0.44860066</td>
</tr>
<tr>
<td>Max</td>
<td>0.046546547</td>
<td>0.03785489</td>
<td>0.219547493</td>
<td>0.051632747</td>
<td>0.459386986</td>
<td>0.60702932</td>
</tr>
<tr>
<td>Min</td>
<td>-0.004350979</td>
<td>-0.001119453</td>
<td>-0.07355889</td>
<td>0.002050247</td>
<td>0.41812985</td>
<td>0.00000000</td>
</tr>
<tr>
<td>Std Dev.</td>
<td>0.013174057</td>
<td>0.011605292</td>
<td>0.024786624</td>
<td>0.011531386</td>
<td>0.016355196</td>
<td>0.075315113</td>
</tr>
<tr>
<td>Obs</td>
<td>970</td>
<td>970</td>
<td>960</td>
<td>970</td>
<td>970</td>
<td>970</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Growth in Cancer deaths per job (MSA)</th>
<th>Growth in Cancer deaths per job (NATION)</th>
<th>Unavailable land share (MSA)</th>
<th>House price elasticity</th>
<th>Wharton Land Use Regulation Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.00430883</td>
<td>0.001036258</td>
<td>0.261474748</td>
<td>1.897790144</td>
<td>0.073577796</td>
</tr>
<tr>
<td>Median</td>
<td>0.000415332</td>
<td>-0.008343488</td>
<td>0.19283633</td>
<td>1.668164492</td>
<td>0.04924999</td>
</tr>
<tr>
<td>Max</td>
<td>0.205606071</td>
<td>0.05556462</td>
<td>0.79646204</td>
<td>5.453317165</td>
<td>1.882059965</td>
</tr>
<tr>
<td>Min</td>
<td>-0.136303455</td>
<td>-0.08477636</td>
<td>0.00316998</td>
<td>0.595260104</td>
<td>-1.231920691</td>
</tr>
<tr>
<td>Std Dev.</td>
<td>0.04312348</td>
<td>0.021239225</td>
<td>0.2091283</td>
<td>0.9204122</td>
<td>0.68382832</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-0.76713036</td>
<td>1.89310399</td>
<td></td>
</tr>
<tr>
<td>Obs</td>
<td>960</td>
<td>970</td>
<td>970</td>
<td>970</td>
<td>970</td>
</tr>
</tbody>
</table>
### Table 1d: Descriptive Statistics for Variables in Equation 27, 180 MSA's, 2006-2010

<table>
<thead>
<tr>
<th></th>
<th>Nominal GDP ($million)</th>
<th>Large Cities Effective Jobs (net of commute time)</th>
<th>Small Cities Effective Jobs (net of commute time)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>66610.86266</td>
<td>53705.1</td>
<td>60962</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>23986</td>
<td>22847.5</td>
<td>62120</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>1280307</td>
<td>7584130</td>
<td>62961</td>
</tr>
<tr>
<td><strong>Min</strong></td>
<td>9637</td>
<td>47593</td>
<td>57844</td>
</tr>
<tr>
<td><strong>Std. Dev.</strong></td>
<td>130187.848132</td>
<td>8655.17</td>
<td>2025</td>
</tr>
<tr>
<td><strong>Obs</strong></td>
<td>865</td>
<td>865</td>
<td>865</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th><strong>“National” Average Effective Jobs, net of commute time</strong></th>
<th><strong>State-level TFP Growth</strong></th>
<th><strong>Federal Funds Rate (National)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>294202</td>
<td>-0.001300865</td>
<td>2.71</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>298095</td>
<td>-0.00264851</td>
<td>3.04</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>301586</td>
<td>0.07566632</td>
<td>5.25</td>
</tr>
<tr>
<td><strong>Min</strong></td>
<td>284771</td>
<td>-0.07467376</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>Std. Dev.</strong></td>
<td>7150</td>
<td>0.025750115</td>
<td>2.19</td>
</tr>
<tr>
<td><strong>Obs</strong></td>
<td>865</td>
<td>865</td>
<td>865</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------------</td>
<td>----------------------------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>Mean</td>
<td>5286.855</td>
<td>62484.478</td>
<td>53804.698</td>
</tr>
<tr>
<td>Median</td>
<td>468.000</td>
<td>9614.069</td>
<td>54838.962</td>
</tr>
<tr>
<td>Min</td>
<td>9631.000</td>
<td>130884.309</td>
<td>55999.439</td>
</tr>
<tr>
<td>Max</td>
<td>2251.000</td>
<td>160814.654</td>
<td>502871.511</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>185.707</td>
<td>25461.809</td>
<td>21944.171</td>
</tr>
<tr>
<td>Obs</td>
<td>905</td>
<td>900</td>
<td>905</td>
</tr>
</tbody>
</table>

State-level TFP Growth

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>Std. Dev.</th>
<th>Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>State-level TFP Growth</td>
<td>-0.0000666</td>
<td>-0.002097</td>
<td>0.075666</td>
<td>-0.074674</td>
<td>0.025222</td>
<td>900</td>
</tr>
</tbody>
</table>
Table 2: Estimation Results for Equation 14, for 76 "Cities", Annual "City-level" Data for 2002, 2007, 2012

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>OLS</th>
<th>RE</th>
<th>RE</th>
<th>OLS</th>
<th>RE</th>
<th>RE</th>
<th>N</th>
<th>N-RE</th>
<th>IV</th>
<th>N-IV</th>
<th>IV</th>
<th>N-IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant</strong></td>
<td>38448.016</td>
<td>39229.077</td>
<td>40507.855</td>
<td>35050.090</td>
<td>37012.726</td>
<td>36043.079</td>
<td>3281.305</td>
<td>3546.979</td>
<td>4829.914</td>
<td>2587.825</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOMESTIC SALES PER JOB</td>
<td>0.045</td>
<td>0.044</td>
<td>0.044</td>
<td>0.044</td>
<td>0.046</td>
<td>0.046</td>
<td>0.047</td>
<td>0.048</td>
<td>0.049</td>
<td>0.049</td>
<td>0.049</td>
<td>0.049</td>
</tr>
<tr>
<td>EXPORTS PER JOB</td>
<td>0.046</td>
<td>0.046</td>
<td>0.046</td>
<td>0.046</td>
<td>0.046</td>
<td>0.046</td>
<td>0.046</td>
<td>0.046</td>
<td>0.046</td>
<td>0.046</td>
<td>0.046</td>
<td>0.046</td>
</tr>
<tr>
<td>TRANSFERS PER JOB</td>
<td>0.622</td>
<td>0.622</td>
<td>0.622</td>
<td>0.622</td>
<td>0.622</td>
<td>0.622</td>
<td>0.622</td>
<td>0.622</td>
<td>0.622</td>
<td>0.622</td>
<td>0.622</td>
<td>0.622</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.598</td>
<td>0.559</td>
<td>0.519</td>
<td>0.590</td>
<td>0.519</td>
<td>0.519</td>
<td>0.519</td>
<td>0.519</td>
<td>0.519</td>
<td>0.519</td>
<td>0.519</td>
<td>0.519</td>
</tr>
</tbody>
</table>

Notes:
- White Robust standard errors in bold
- FE is "cross-sectional fixed effects"
- RE is "cross-sectional random effects"
- All variables are in "real" terms, 2005 dollars
- ****, ***, **, * indicates the coefficient is statistically significantly different from 0 at the 0.001, 0.01, 0.05, 0.10 levels, respectively
- ttttt, tttt, tt, t indicates the coefficient is not statistically significantly different from 1 at the 0.10, 0.05, 0.01, 0.001 levels, respectively (a larger number of symbols indicates greater degree of confidence that the coefficient equals 1)

Instruments include:
- for domestic shipments: lagged "planned highway rays" per-capita, lagged miles of highways completed (inside the city), and the difference between national population and city population
- for transfers: real unemployment insurance receipts per person
- for exports: real exports per person
- Is the instrument for itself
- for constant term (where applicable): Is the instrument for itself.
<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>OLS</th>
<th>Fixed Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSTANT</td>
<td>-3.984608</td>
<td>1.043285</td>
</tr>
<tr>
<td></td>
<td>0.0050</td>
<td>0.8872</td>
</tr>
<tr>
<td>MSA CPI GROWTH - URBAN CPI GROWTH</td>
<td>5.644318</td>
<td>6.299464</td>
</tr>
<tr>
<td></td>
<td>0.0006</td>
<td>0.0001</td>
</tr>
<tr>
<td>N</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.044416</td>
<td>0.364512</td>
</tr>
</tbody>
</table>
Table 4: Estimation Results for Equation 20, 96 MSA’s, Annual Data, 2003-2012

Spatial Equilibrium Equation

Dependent Variable: MSA House Price Growth Rate - National House Price Growth Rate

P-Values in bold

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>OLS</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-1.9343</td>
<td>-1.0584</td>
</tr>
<tr>
<td></td>
<td>0.3419</td>
<td>0.7706</td>
</tr>
<tr>
<td>REGIONAL CPI Growth - Urban CPI Growth</td>
<td>-0.2893</td>
<td>-1.3505</td>
</tr>
<tr>
<td></td>
<td>0.4126</td>
<td>0.1024</td>
</tr>
<tr>
<td>MSA GDP growth per capita - National GDP Growth per capita</td>
<td>0.2943</td>
<td>4.2281</td>
</tr>
<tr>
<td></td>
<td>0.0009</td>
<td>0.0347</td>
</tr>
<tr>
<td>(MSA Employment per-capita)(^{1/2})</td>
<td>-0.0076</td>
<td>0.0411</td>
</tr>
<tr>
<td></td>
<td>0.1121</td>
<td>0.5035</td>
</tr>
<tr>
<td>(-1)×(National Employment per-capita)(^{1/2})</td>
<td>0.2816</td>
<td>0.2032</td>
</tr>
<tr>
<td></td>
<td>0.3519</td>
<td>0.7062</td>
</tr>
</tbody>
</table>

| N                     | 960       | 960       |
| R-squared             | 0.0368    | *         |
| J-Statistic           | -         | 0.1217    |

Note: All models include region and year fixed effects

Instruments for IV Estimation:
- Unavailable Land Area;
- Wharton Regulation Index;
- House Price Elasticity;
- MSA Cancer Growth - National Cancer Growth

*R-squared from IV may be negative, in which situation it is not useful to report (Wooldridge, 2006)
Table 5: Estimation Results for GDP growth rate regressions, panel data (annual-level, MSA)

<table>
<thead>
<tr>
<th>Dependent Variable: Nominal GDP Growth Rate</th>
<th>Trading City Model</th>
<th>Trading City Model</th>
<th>Trading City Model</th>
<th>Trading City Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent Variables</td>
<td>Large cities (eq 27)</td>
<td>Small cities (eq 28)</td>
<td>All Cities</td>
<td>All Cities</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>0.0203</td>
<td>0.1487</td>
<td>0.1967</td>
<td>0.0164</td>
</tr>
<tr>
<td>MSA-Level Total Factor Productivity Growth</td>
<td>0.0077</td>
<td>0.0085</td>
<td>0.0080</td>
<td>0.0074</td>
</tr>
<tr>
<td>Own-City Net Employment Growth Rate</td>
<td>0.0807</td>
<td>0.0812</td>
<td>0.0025</td>
<td>0.0051</td>
</tr>
<tr>
<td>Average Net Employment Growth Rate, Other City Type</td>
<td>-0.0097</td>
<td>-0.0067</td>
<td>-0.0087</td>
<td>-0.0093</td>
</tr>
<tr>
<td>National Net Employment Growth Rate</td>
<td>0.0030</td>
<td>0.0122</td>
<td>0.0025</td>
<td>0.0025</td>
</tr>
<tr>
<td>Interest Rate (federal funds rate) Growth Rate</td>
<td>0.0616</td>
<td>0.0627</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>State-Level Private Capital Stock Growth</td>
<td>0.0206</td>
<td>0.0112</td>
<td>0.0033</td>
<td>0.0031</td>
</tr>
<tr>
<td>Year Dummy for 2007</td>
<td>-0.0040</td>
<td>0.0036</td>
<td>0.0023</td>
<td>0.0023</td>
</tr>
<tr>
<td>Year Dummy for 2008</td>
<td>-0.0576</td>
<td>-0.0243</td>
<td>-0.0155</td>
<td>-0.0148</td>
</tr>
<tr>
<td>Cross Sections (number of cities)</td>
<td>0.0128</td>
<td>0.0086</td>
<td>0.0041</td>
<td>0.0041</td>
</tr>
<tr>
<td>N</td>
<td>382</td>
<td>187</td>
<td>350</td>
<td>353</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.6315</td>
<td>0.5697</td>
<td>0.5926</td>
<td>0.5838</td>
</tr>
</tbody>
</table>

All regressions estimated by OLS, include cross-sectional fixed effects.

Large cities in a particular year are defined as cities with GDP above the median of all MSA’s GDP; small cities with GDP below median

Interest Rate based on Federal Funds rate, national level estimates

"Net Employment" refers to employment net of commuting time. See the text for a description of how this is calculated.
Simulations of a 10% Shock in Value of a City's International Exports on the City's Growth in Housing Prices Relative to National Average
Simulations of a 10% Shock in Value of a City's Domestic Shipments on the City's Growth in Housing Prices Relative to National Average
Simulations of a 10% Shock in Value of Transfers on the City's Growth in Housing Prices Relative to National Average

Growth Rate in City Housing Prices Relative to National Average

Albany, NY
Atlanta, TX
Baltimore, MD
Boston, MA
Buffalo, NY
Charlotte, NC
Cincinnati, OH
Cleveland, OH
Columbus, OH
Dayton, OH
Denver, CO
Detroit, MI
Grand Rapids, MI
Greensboro, NC
Greenville, SC
Houston, TX
Indianapolis, IN
Jacksonville, FL
Las Vegas, NV
Los Angeles, CA
Louisville, KY
Memphis, TN
Milwaukee, WI
Minneapolis, MN
Nashville, TN
New Orleans, LA
Virginia Beach, VA
Salt Lake City, UT
Oklahoma City, OK
Philadelphia, PA
Phoenix, AZ
Pittsburgh, PA
Portland, OR
Richmond, VA
Rochester, NY
San Diego, CA
San Francisco, CA
Seattle, WA
Tampa, FL

DEP_VBLE_TRANSFERS_SHOCK

2 S.E.