Ports, Trade, Employment, and Local Factor Prices:

An Urban Equilibrium Theory*

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Abstract

In this study, I develop a multi-sector urban equilibrium model of port cities that allows one to consider the disaggregated employment and factor price effects of domestic and international transportation. The model resolves the theoretical ambiguity of aggregate urban equilibrium effects in response to changes in the utilization of port infrastructure by considering the opposing industry-specific dynamics across manufacturing, transport, and service sectors. The research highlights the simultaneity between trade, transport, and the urban economy and delivers an estimable system of equations to overcome this issue.

JEL codes: (F16, J30, R11, R40)

Key words: Employment; Factor prices; Port City; Infrastructure; Transport services;

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1 Introduction

The economic impact of public capital infrastructure investments and its utilization is a heavily debated subject with a longstanding history in the economic literature.[1] One of the primary points of disagreement is the quantification of economic benefits[2], which is complicated by the simultaneous determination of investment location, infrastructure utilization, and surrounding economic activity. One the one hand, local economic activity, for example, may lead to exports facilitated through the local port of exit. On the other hand, port investments and the services provided by the port may also stimulate the local employment growth. As greater port utilization creates opportunities for some agents (i.e., market access) and challenges for others (i.e., congestion), the associated changes in port-city employment coincide and are affected by simultaneously adjusting factor prices; and aggregate changes in these economic conditions are subject to sector-specific responses and the economy's industry composition.

In this paper, I build on previously studied urban equilibrium frameworks (Roback 1982; Haughwout 1996, 2002; Wu and Gopinath 2008) and derive a general equilibrium model to evaluate the aggregate and industry-specific effects of an increase in transport infrastructure services on employment and factor prices. Specifically, I develop a multi-sector urban equilibrium model that differentiates across goods-, service- and transport-producing firms and formally integrates domestic and international transport services.

The theory lends itself to evaluate the effects of changes in infrastructure utilization, such as changes in the volume of port throughput. While the aggregate jurisdictional responses to an increase in seaport services or reduction in international transport costs are indeterminate, the more disaggregated sectoral-level analysis shines a light on the underlying industry-specific effects. Several competing mechanisms that align with the previous literature and influence the aggregate outcome emerge. These include: 1) the productivity-enhancing supply shock on manufacturing industries resulting from the reduction in international transport cost, greater accessibility and the

[1] Examples of early studies in this field are given by (Ciriacy-Wantrup 1955) or (Mohring 1961).

[2] Gramlich (1994); Gillen (1996); Jiang (2001); Pereira et al. (2013) have provided excellent surveys on this debate and offer key insights into the potential sources driving the divergence of the initial estimates.

enhanced market potential (Fujita et al. 2001); 2) the positive demand shock for local transport and transport-related service sectors (Chandra and Thompson 2000); 3) the adverse supply shocks on non-tradable goods and service industries arising from the increases in domestic transport costs and congestion (Fernald 1999); and 4) the dis-amenity effect of increased congestion experienced by households (Monte et al. 2018).

Identifying these industry-specific predictions and understanding how each mechanism shapes the aggregate economic impact in response to changes port utilization has policy relevance. First, international trade has been growing for decades, and growing at a rate well out-pacing global output. As a result, the share of trade and the demands on international transportation networks have been rising drastically. In 2016, U.S. trade topped 3.5 trillion dollars requiring annual shipments of over 48 million containers according to The World Bank (2016). As over 80% of international shipments are seaborne (Asariotis et al. 2017). 2017), seaports are the primary gateways connecting domestic and international markets. Given the magnitude of annual cargo flows, it is important to understand how the facilitation of international trade impacts local labor markets tied to these gateways (Acemoglu et al. 2005).

Second, the theory offers new perspectives on the effects of traditional trade and other related public policies. What is the impact of a sudden change in the shipment patterns of international trade? How does a change in the utilization of available infrastructures affect local labor markets and factor prices? Do reductions in transport costs, greater accessibility and increased market potential result in a surge of local employment and factor prices, or does the increase in transport services trigger a substitution away from labor and cause dis-amenities due to worsening congestion and pollution?

Causes of changes in port utilization are manifold. Whether it is a sudden diversion of trade due to a natural disaster, intermediate changes in trade routes due to an escalating trade war, or long-term shifts in trade patterns due to infrastructure investments or the ascension of Asian trade partners. Each can shift the patterns of U.S. trade and transportation across the U.S. network of East, West, and Gulf Coast ports. By shedding light on the interdependence of the urban economy and port services the theory informs these policy-relevant questions.

Finally, the empirical literature on the economic impacts of infrastructure has struggled to capture the intensive margin effects of its efficient utilization (Baird 2005) and tends to be subject to endogeneity concerns (Friedt and Wilson 2020). My research contributes to this vast literature on the economic impacts of transport infrastructure delivering an estimable system of simultaneous equations of employment, wages, land rents and transport services that can be used to quantify the economic impact of port services, while addressing the persistent issue of endogeneity.

The paper proceeds as follows. In section 2, I develop a multi-sector model that extends previous urban equilibrium theory. In section 3, I solve for the equilibrium conditions and use the model to elaborate on the competing channels through which seaport services for internationally traded goods may influence the urban equilibrium outcome. Based on this theory, in section 4, I derive a system of simultaneous equations that can guide future empirical analyses quantifying the economic impact of port utilization. Section 5 offers a brief discussion of potential limitations and extensions, while section 6 concludes the paper.

2 Theory

The theoretical model extends the derivation by Haughwout (1996, 2002) and is based on an economy consisting of many political jurisdictions with set boundaries. Land is owned by landlords who are otherwise absentee from the economy. Households and firms are assumed to locate freely across these jurisdictions, but are unable to commute across boundaries once the location has been determined.[3] The location choice for households and firms is influenced by a variety of determinants including, for example, fiscal policy measures, such as taxation and the provision of public goods, and other amenities that are taken as given by these economic agents. In contrast, the en-

[3]This assumption creates distinct labor markets across jurisdictions and is a matter of tractability. While the theoretical integration of free labor mobility goes beyond the scope of this study, the empirical analysis considers the possibility of spatial spillovers that transcend county lines. For the interested reader, Allen and Arkolakis (2014), Albouy and Farahani (2017) and Monte et al. (2018) address this issue in spatial equilibrium context. Albouy and Farahani (2017), for example, expand the model to incorporate restricted labor mobility. The intuitive result suggests that the restriction of labor mobility and location choice enhances the value of local amenities and infrastructure.

dogenously adjusting location determinants consist of the local output and factor prices prevailing in each jurisdiction. The key distinctions to the previous work by Haughwout (1996, 2002) are the differentiation across multiple industries and the inclusion of domestic (d) and international (i) transport services and prices. Ultimately, the model I develop in this study yields an expression for the urban equilibrium that consists of local labor, land, capital and transport markets, from which the effects of a change in international transport services[4] on various industries and households can be considered.

2.1 Households

Households provide one unit of labor earning the prevailing wage rate (W). Utility is derived from the consumption of an all-purpose manufactured consumption good (Q_M) and local services (Q_S), the use of land (L), as well as the consumption of public goods (G) and amenities (A). While public goods can be thought of as libraries, public schools, hospitals, or transport infrastructure, amenities may include climatic conditions or accessibility of financial institutions, among others. I augment the original model by Haughwout (1996, 2002) and postulate that households further derive utility from local domestic transport services (T_d) offered within a given jurisdiction. For households, these may include the use of public transit as well as the ease of personal commutes utilizing the existing transport infrastructure network.[5] Households are assumed to be utility maximizing subject to a budget constraint stating that net wage income must equal expenditure on goods and services, land, and local transport. The resulting utility maximization problem for household (H) choosing the level of consumption of goods and services, land, and domestic transport is given as follows:

$$\max_{Q_M,Q_S,L,T_d} U_H(Q_M, Q_S, L, G, A, T_d) \qquad \text{s.t.} \qquad (1-t_y)W = Q_M + p_S Q_S + RL + \tau_d T_d, \quad (1)$$

[4]Changes in international transport services may include a change the range of services offered by a given port or a change in the quality of the service provided. International transport costs may also change through variation in port throughput changing the scale or utilization of the port's operation.

[5]For empirical evidence on the importance of local commuting costs to the location decision of workers see Monte et al. (2018).

where wage income is net of income taxes (t_y), the price of manufactured goods is normalized to one and the prices of services, land, and domestic transport are given by p_S, R and τ_d.

Since all households are price takers, the solution to the household's maximization problem provides four household demand (D) functions[6] for goods and services, land, and domestic transport

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\begin{aligned}
&Q_{HM}^D = Q_{HM}^D(W, R, t_y, p_S, \tau_d, G, A),\\
&Q_{HS}^D = Q_{HS}^D(W, R, t_y, p_S, \tau_d, G, A),\\
&L_H^D = L_H^D(W, R, t_y, p_S, \tau_d, G, A),\\
&T_{H,d}^D = T_{H,d}^D(W, R, t_y, p_S, \tau_d, G, A).
\end{aligned} \tag{2}
$$

Substitution of these demand equations back into the utility function yields indirect utility:

$$V(W, R, t_y, p_S, \tau_d, G, A) = V_0. \tag{3}$$

As households can choose their location freely, this indirect utility must be equal across all jurisdictions. In other words, given a certain set of fiscal policies, public goods, and amenities, as well as the prices of goods, services and local transport, wages and land rents must adjust so that every household enjoys a utility level of V_0 and is indifferent between locations. A jurisdiction with better transport services, for example, is more attractive to households, who in turn are willing to settle in this jurisdiction despite potentially lower wages and/or higher land rents.

Assuming local nonsatiation of utility, this relationship can be expressed analytically by taking the inverse of the indirect utility and solving for the household's "wage demand" function (Haughwout 1996):

$$W_H^D = E(R, t_y, p_S, \tau_d, G, A, V_0). \tag{4}$$

Aside from goods, service, and domestic transport prices, as well as the exogenously de-

[6]See appendix for a more detailed derivation.

termined fiscal policy and local amenities, this wage demand function is equivalent to the Varian (1992) household's expenditure function determining the minimum wage that is necessary to achieve a utility of V_0 conditional on these local characteristics. This, of course, implies that households demand compensation for undesirable conditions, such as an increase in goods or services prices, land rents, income taxes, or local transport costs. On the other hand, wages are decreasing in outcomes that are deemed desirable, including public goods and local amenities.

Conditional on these jurisdictional characteristics, an improvement in utility - for any reason - attainable in other locations (V_0), all else equal, makes workers in a given location demand higher wages $\frac{\partial W_H^D}{\partial V_0} > 0$, in order for these workers to choose to stay. The solid black line in Figure 1.1 represents the household's wage demand function and illustrates the positive relationship between wages and land rents. An increase in local property prices must be compensated with higher jurisdictional wages in order to retain the same level of utility.

2.2 Firms

To investigate the urban equilibrium response to a disaster-induced rerouting of international transport services and explore the industry-specific impacts, I further extend the work by Haughwout (1996) and assume that there are three types of firms (manufacturing=M, services=S, transport=T) that produce either manufactured consumption goods (Q_M), services (Q_S), or domestic transportation (T_d). Labor is free to move across industries, but only within jurisdictional boundaries. Considering the goods- and services-producing firms, the key distinction between these industries is the assumption that the production of the manufactured product (Q_M) requires an intermediate input (θ), sourced internationally (i). For simplicity, I assume that θ is supplied inelastically and that the foreign export price of this intermediate product (p_θ) is taken as given by domestic firms. To source the intermediate good from overseas, each manufacturing firm must incur the international iceberg transport cost (τ_i), typically assumed in the trade literature.[7] As a result, the import price per unit

[7]There are many models of international trade, including those that incorporate an international transport sector (see, for example, Friedt and Wilson 2020), from which the supply and transport of the international intermediate good can be derived. The development of this multi-country setting, however, distracts from the domestic urban equilibrium

of the intermediate good is simply given by $\tau_i p_\theta$. Based on this structure, service firms solely demand the aforementioned domestic transport services (T_d) per unit produced and distributed within a given jurisdiction, while manufacturing firms require both domestic and international transport services (T_i) to bring one unit of the consumption good to market. For simplicity, I assume that the manufacturing firm requires one unit of T_i to ship one unit of the intermediate input (θ) from the foreign supplier to the jurisdictional port of entry. As such, the demand for T_i is analogous to the demand for θ and for remainder of this study, I use T_i to represent the demand and shipment of the internationally-sourced intermediates. Within each jurisdiction, local transport firms supply the domestic transport services distributing of final outputs and internationally-sourced intermediates.

Similar to households, I assume that each type of firm is free to locate across political jurisdictions and maximizes profits. Further, I follow Haughwout (1996) and assume that every firm's production function is subject to constant returns to scale (CRTS) and that input as well as output markets are perfectly competitive. Since labor is perfectly mobile across industries, these assumptions imply that all firms are price takers with respect to all factor inputs, including transportation, and that wages must equalize across industries within a jurisdiction. Based on these assumptions, the respective optimization problems for each type of firm can be represented as follows:

$$\min_{N,K,L,T_d} C_S = WN + rK + RL + \tau_d T_d \quad \text{s.t.} \quad S(N,K,L,T_d,G,A) = 1, \tag{5}$$

$$\min_{N,K,L,T_d,T_i} C_M = WN + rK + RL + \tau_d T_d + \tau_i p_\theta T_i \quad \text{s.t.} \quad M(N,K,L,T_d,T_i,G,A) = 1, \tag{6}$$

$$\min_{N,K,L} C_T = WN + rK + RL \quad \text{s.t.} \quad T_d(N,K,L,G,A) = 1, \tag{7}$$

where goods- and service-producing firms choose the required transport services (T_d, T_i) and every type of firm employs labor (N), private capital (K) and land (L) to minimize their respective per unit cost. While the factor prices of labor, land and transport services are as previously defined (W, R, τ_d, τ_i), the price of private capital is determined at the national level and given by r.

The solution to these cost minimization problems yields each type of firm's demands for labor,

focus and goes beyond the scope of this study. Instead, I assume that international transport supply is perfectly inelastic and that the price of these transport services is exogenously determined and taken as given by all firms.

land, private capital and domestic as well as international transport services:

$$\begin{aligned}
&\textit{Labor}: && N_S^D = N_S^D(W,R,r,\tau_d,G,A) && N_M^D = N_M^D(W,R,r,\tau_d,\tau_i p_\theta,G,A) && N_T^D = N_T^D(W,R,r,G,A),\\
&\textit{Land}: && L_S^D = L_S^D(W,R,r,\tau_d,G,A) && L_M^D = L_M^D(W,R,r,\tau_d,\tau_i p_\theta,G,A) && L_T^D = L_T^D(W,R,r,G,A),\\
&\textit{Capital}: && K_S^D = K_S^D(W,R,r,\tau_d,G,A) && K_M^D = K_M^D(W,R,r,\tau_d,\tau_i p_\theta,G,A) && K_T^D = K_T^D(W,R,r,G,A),\\
&\textit{Transport}: && T_{Sd}^D = T_{Sd}^D(W,R,r,\tau_d,G,A) && T_{Md}^D = T_{Md}^D(W,R,r,\tau_d,\tau_i p_\theta,G,A) && T_{Mi}^D = T_{Mi}^D(W,R,r,\tau_d,\tau_i p_\theta,G,A).
\end{aligned} \quad (8)$$

Here, T_{Mi}^D represents the demand for international transport services of a manufacturing firm, while T_{Md}^D represents the demand for domestic transport services of that same firm. Substitution of these demands back into each type of firm's cost function yields

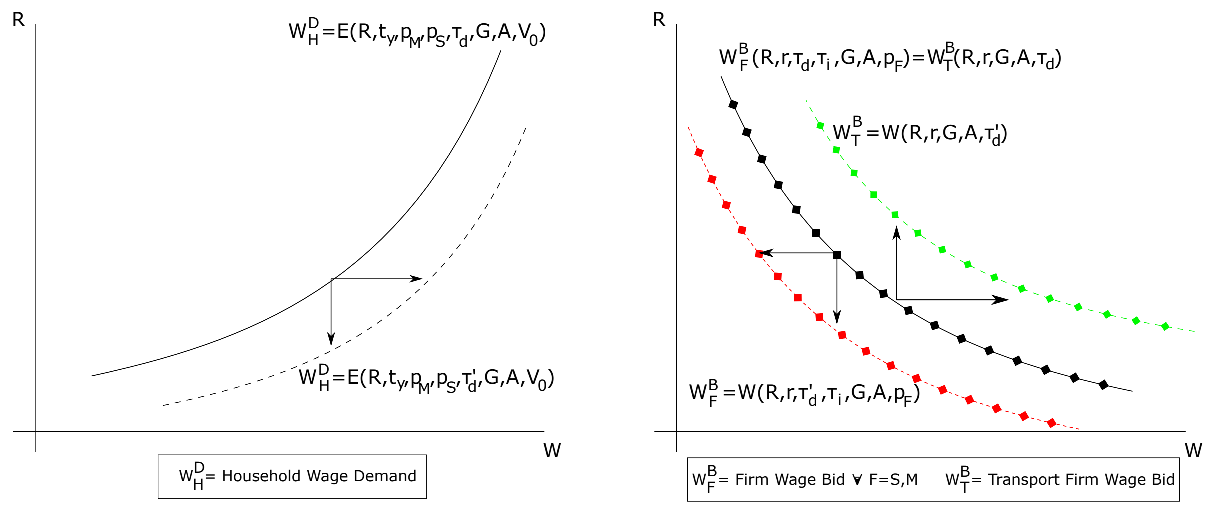
$$C_S(W,R,r,\tau_d,G,A) = p_S; \quad C_M(W,R,r,\tau_d,\tau_i p_\theta,G,A) = p_M; \quad C_T(W,R,r,G,A) = \tau_d, \quad (9)$$

which express the minimum cost per unit of S, M and T_d as functions of the respective input prices and local conditions exogenous to every firm. Moreover, the expressions under Equation (9) impose the respective zero profit conditions, that cost per unit must equal the price per unit (p_S, p_M, τ_d), which follows from the free location choice of each firm. If prices were to rise in a given jurisdiction, all else equal, firms would seize the resulting profit opportunity, switch locations and drive up local factor prices until the minimum cost per unit would rise to the new price level.

Inverting these expressions and solving for the equilibrium jurisdictional wage yields each type of firm's "wage bid" (B) function (Haughwout 1996)

$$W_S^B = W_S^B(R,r,\tau_d,G,A,p_S); \quad W_M^B = W_M^B(R,r,\tau_d,\tau_i p_\theta,G,A,p_M); \quad W_T^B = W_T^B(R,r,G,A,\tau_d) \quad (10)$$

Intuitively, wages are increasing in labor-productivity-enhancing public goods and local amenities, but decreasing in other factor prices. As previously suggested, an increase goods or services prices will result in an increase in local wages, $\frac{\partial W_F^B}{\partial p_F} > 0 \ \forall F = S, M$, ceteris paribus. Finally, jurisdictions with higher land rents, all else equal, must exhibit lower wage bids across all industries. This inverse relationship is illustrated by the solid black wage-bid curve shown in Figure 1.2.



1.1: Household Wage Demand Function

1.2: Firm Wage Bid Function

Figure 1: Wage demand and bid functions

3 Equilibrium

The equilibrium in this model characterizes the optimal decisions for households and firms in each of the three sectors conditional on external determinants (local amenities, infrastructure, etc.) and endogenously adjusting factor prices. More formally, the equilibrium in this model is defined by the set of factor and output prices (W^*, τ_d^*, p_S^* and p_M^*), as well as labor (N_S^*, N_M^*, N_T^*), land (L_S^*, L_M^*, L_T^*), capital (K_S^*, K_M^*, K_T^*) and transport (T_{Hd}^*, T_{Sd}^*, T_{Md}^* and T_{Mi}^*) quantities, such that a) the optimization conditions of each agent are satisfied (Equations (4), (9), (10)) and b) the markets for labor, land, capital, and transport clear.

Again, Equations 4 and 9 provide the factor and output price conditions that we can derive by imposing the utility equivalence and zero profit conditions arising from the assumptions of free household and firm location choices, as well as perfectly competitive input and output markets. In other words, in equilibrium the vector of local factor prices (wages and land rents) across all jurisdictions is such that households and firms are indifferent between the location they have chosen and any other jurisdiction. Together, these equations represent the spatial equilibrium conditions for the urban model developed here.

Market clearing conditions can be expressed as follows:

$$\begin{aligned} &N^* = N_S^* + N_M^* + N_T^* && L_H^* + L_S^* + L_M^* + L_T^* = L_0 \\ &K_S^* + K_M^* + K_T^* = K_0 && T_{Hd}^* + T_{Sd}^* + T_{Md}^* = T_d^* \\ &T_{Mi}^* = T_{i0}. && \end{aligned} \tag{11}$$

Asterisks indicate the equilibrium value of a given variable, while L_0, K_0 and T_{i0} represent the available land, private capital and international transport services offered in a given jurisdiction. The individual demand functions underlying the market clearing conditions are given by the collection of Equations in (2) and (8).

3.1 Comparative Statics

The model lends itself to evaluate the equilibrium effects of changes in the domestic and international transport sectors. Given the dependence of local firms and households on these transport sectors, changes in trade flows, even if they originate in or are destined for other jurisdictions, can impact local port-city economies through changing local transport costs.

Overall, the model points to considerable theoretical ambiguity with regards to the average equilibrium impact on local factor prices. In general, this aggregate ambiguity is driven by the heterogeneity in the underlying industry-specific effects that are often opposing to one another. The competing channels include 1) the productivity-enhancing supply shock on manufacturing industries resulting from the reduction in domestic and/or international transport cost, for example; 2) the positive demand shock for local transport and transport-related service sectors (Chandra and Thompson 2000); 3) the adverse supply shocks on non-tradable goods and service industries competing for domestic transport services and facing additional congestion (Fernald 1999); and 4) the dis-amenity effect of increased congestion experienced by households (Monte et al. 2018).[8]

[8]Another potential channel through which a reduction in international transport costs may influence the urban equilibrium is the adverse affect of intensifying foreign competition on local manufacturing firms. This effect would take hold if the reduction in international transport costs through the local port of entry improves market access for

3.1.1 Change in Domestic Transport

Consider, for example, a jurisdictional-specific rise in the domestic transport price ($\tau_d' > \tau_d$). In this case, households that live within this jurisdiction experience a dis-amenity effect from higher transport costs. The respective jurisdiction becomes less attractive to households. Households now have a choice between relocation to an unaffected location or staying in the affected jurisdiction. For them to stay, all else equal, households require greater wage compensation and/or lower land prices in return. This household response is captured by the downward shift in the wage demand function represented by the dotted black line in Figure 1.1.

Simultaneously, goods- and service-producing firms experience an adverse supply shock from increasing transport costs that needs to be offset by a reduction in wage bids and/or lower land prices. For simplicity, assume all firms start from the same initial wage bid function, as shown in Figure 1.2. These responses by manufacturing and service firms are then captured by the downward shift in the wage bid functions represented by the dotted red line in Figure 1.2. Based on these adjustments alone, the rise in domestic transport cost leads to a clear reduction in equilibrium land values, while the effect on wages is ambiguous.

To complicate the aggregate effects further, however, we also need to consider the local transport sector. For this industry, the increase in domestic transport prices reflects a positive demand shock and results in higher wage bids and greater land price offers that counteracts the decline in land values driven by the impact on other industries and households. Graphically, this transport firm response is captured by the upward shift in the firm's wage bid function represented by the dotted green line in Figure 1.2.

Transitioning to the new equilibrium, the worsening of local transport costs and sectoral dif-

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foreign firms. As the international trade literature, however, suggests (see, for example, Autor et al. (2013) or Kovak et al. (2017)), import competition takes place in destination, rather then origin markets. Unless the local port of entry is (or becomes) the gateway for international firms to ship to their destination markets, a local reduction in international transport costs is unlikely to change the competitive landscape in destination markets. For example, firms located near the port of Panama City, FL, may compete with international firms in markets located in Miami, Houston, or the East Coast. International firms likely ship directly through the ports of Miami or Houston. A reduction in transport costs through the port of Panama City, FL, is unlikely to impact foreign firms and therefore does not necessarily intensify foreign competition. For the purposes of this study, I ignore any potential changes in international competition.

ferences in response to this change must lead to labor market adjustments across industries. First, land values and/or wages prevailing in this jurisdiction must fall to re-establish utility equivalence and zero-profit condition across locations. Second, to re-establish the uniform jurisdictional wage across industries, local laborers will reallocate towards the transport sector and reduce the marginal product of labor (MPL) in this industry. Vice versa, the marginal product of the remaining workers in the goods- and service-producing industries must rise. As such, the movement of labor will offset the opposing wage responses and settle on a new equilibrium wage. Whether this new equilibrium wage is above or below the previous wage depends on the jurisdictional industry composition and the influence of household preferences.

3.1.2 Change in International Transport

Another interesting case to consider is the impact of changes in international transport services. Examples may include shifting macroeconomic trade patterns due to a trade war or sudden changes in local routing choices due to the destructive effects of a natural disaster.[9] In either case, changes in international transport service will have an impact on port-city economic activity. All four of the aforementioned channels will be at play.

First, interviews with the relevant port authorities suggest that changes in shipping routes of international-going vessels imply that a newly called port can offer more frequent and diverse services to manufacturing firms in the local port jurisdiction, which reduces the cost of importing internationally-sourced intermediate inputs and exporting locally produced goods. As a result, manufacturing firms experience a productivity-enhancing supply shock and, in response, raise their wage bids and land price offers, while simultaneously increasing their demand for labor, land, capital and domestic transport services.

Second, in addition to these primary responses in the manufacturing sector, there is a secondary mechanism through which the urban equilibrium is affected. Domestic transport firms servicing the port jurisdiction experience an increase in demand to facilitate the hinterland distribution of

[9]Friedt (2021) shows that natural disasters, such as hurricane Katrina, can lead to persistent rerouting of international cargo through otherwise unaffected ports of entry.

the internationally-sourced intermediate good. This exogenous positive demand shock for local transport results in a rise in domestic transport costs, the effects of which are already summarized in the previous analysis. As a result, both manufacturing and transport firms will raise wage bids in response to the fall in international transport costs.

Third, service-sector and manufacturing firms face an increase in competition for local transport services and worsening congestion on the existing network. This results in a adverse supply shock in both industries. In the non-tradable service sector this leads to a reduction in wage bids. In contrast, in the manufacturing sector the increase in domestic transport costs signifies a feedback effect that partially offsets the aforementioned productivity-enhancing effects of the international transport cost reduction.

Fourth and final, a rise in domestic transport costs and increase in congestion has an adverse effect on households. In response to this increasing dis-amenity, households will require greater wage compensation and lower land values in return. The wage demand function increases.

Again, inter-industry dynamics will lead to a reallocation of workers towards manufacturing and domestic transport industries away from the service sector. The equilibrium effects on factor prices are less clear. Assume for example, that the affected jurisdiction's industry composition is such that the productivity-enhancing shock on manufacturing firms (net of the feedback effect) and the positive demand shock on domestic transport firms outweigh the adverse supply shock experienced in service sectors. In this case, wage bids will increase in aggregate. See, for example, the outward shift of the wage bid function in Figure 2. As discussed, wage demands will also increase. Therefore, wages will unambiguously increase under this assumption, while the magnitude of this change hinges on the size of the shifts. Equilibrium land values, however, may rise or fall depending on the size of the dis-amenity effect on households relative to the aggregate impact on industries. Figure 2 shows that when the change in wage demand is moderate (Case 1), land values will rise to R1 and wages will rise to W1. If wage demands react by more (Case 2), land values will fall to R2 while wages will rise to W2 in response to a reduction in international transport costs.

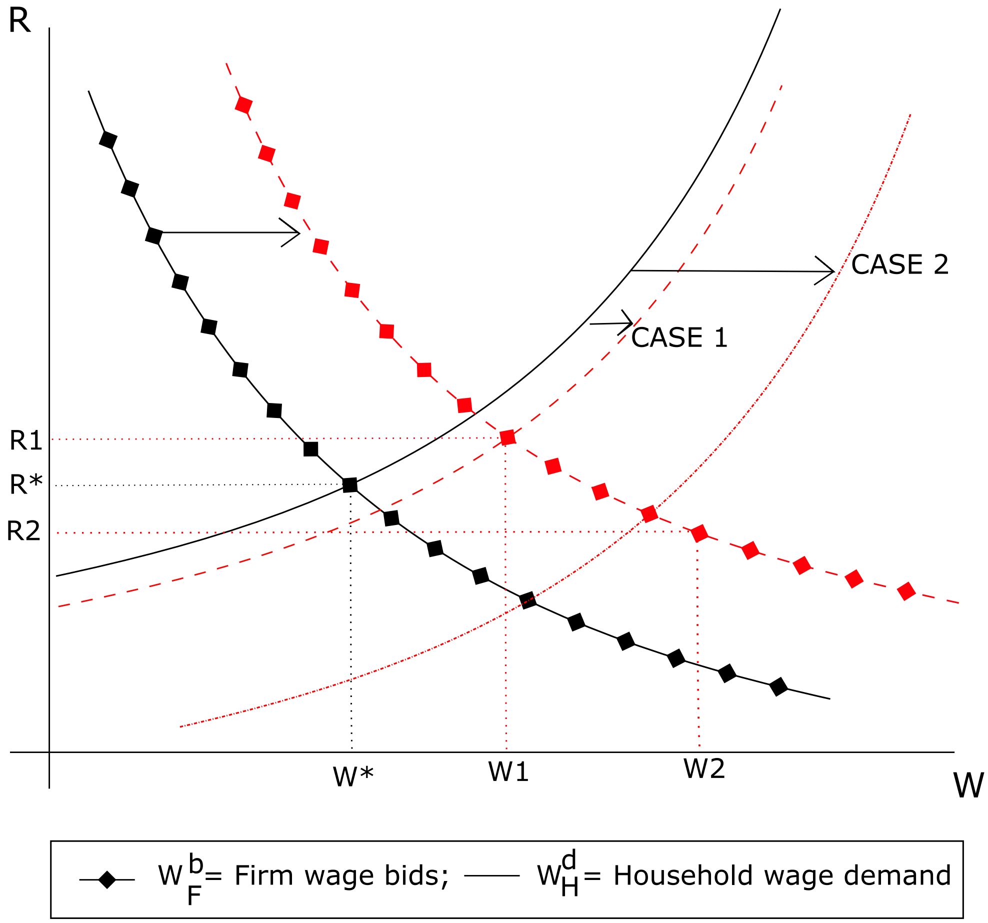

Figure 2: Equilibrium response to a reduction in int'l transport costs

When industry composition sways towards the service sector the ambiguity is reversed. In this case, aggregate wage bid function will fall and wage demand will increase. Equilibrium land values will unambiguously fall, whereas the wage effect is indeterminate.

Overall, these findings match the conclusion drawn by Haughwout (1996), who evaluates the urban equilibrium response to changes in local infrastructure (G), rather than transport services. In both of these studies, simultaneity is the root cause of this ambiguity and points to the limitations of many production function and employment regressions that ignore the endogenous adjustment of local factor prices. Unlike Haughwout (1996), however, the model presented here allows one to dive deeper into the mechanisms that drive this aggregate ambiguity. Sectoral-level difference in their responses to changing domestic and international transport market conditions lead to opposing and ambiguous aggregate dynamics, but clear and testable industry-level hypotheses.

4 Estimatable System of Equations

Theoretically, the urban equilibrium can be determined by simultaneously solving the collection of structural equations. In reality, however, the solution can be obtained recursively in two separate steps. First, factor and output prices of land, labor, domestic transport and services are determined via Equations in (4) and (9). Second, conditional on these prices, household and firm equilibrium choices regarding land, labor, private capital and transport services can be separately derived via the collection of equations in (2) and (8) as well as the market clearing conditions (11). This key feature can guide an empirical model specification. Instead of estimating all structural equilibrium conditions simultaneously to determine the effect of transport services on employment and factor prices, the econometric analysis can focus on factor prices determined by Equations (4) and (10) and individual employment conditions given by the set of equations in (8). Since factor prices must equalize across industries, one can focus on jurisdictional-level analyses and frame the empirical model via four structural equations that capture the prevailing jurisdictional wage rate, land values, and local transport costs, as well as the relevant employment condition. These include aggregate jurisdictional employment as well as sectoral-level analyses.

The resulting empirical model is based on the simultaneously determined equilibrium employment and factor price conditions, including wages, land rents and domestic transport costs:

$$R = R(W, G, A, r, \tau, C) \tag{12}$$

$$W = W(R, G, A, r, \tau, H) \tag{13}$$

$$N = N(R, W, G, A, \tau, r, \lambda) \tag{14}$$

$$\tau = \tau(R, W, G, A, r, Z), \tag{15}$$

Following the theory, equation (12) describes property values as a function of the prevailing local wages, fiscal policy and provision of public goods (G), local amenities (A), local transport conditions (τ), the national price of private capital (r) and local housing market and home characteristics (C). Simultaneously, wages are determined as a function of the prevailing local property values, fiscal policy and amenity controls, local transport conditions, the price of private capital, and exogenous jurisdictional household characteristics (H). In line with Haughwout (1996), these exogenous housing market and household characteristics are required to identify the wage and land value equations and must serve as instruments for these endogenously adjusting factor prices.

Aggregate or sectoral employment is modeled as a function of local wages and property values, along with fiscal policy and amenity controls, local transport conditions, the price of private capital and labor market conditions (λ). These labor market characteristics, such as industrial composition and population density, can be interpreted as controls for the relative county-industry dependence on internationally-sourced intermediates and control for the size of the jurisdictional market.

Lastly, the estimatable system of equations must include a local transport condition. Equation 15 expresses local transport services as a function of the prevailing factor prices, fiscal policy and amenity controls, the national economic conditions. To identify the system, one requires an instrumental variable (Z) that delivers an exogenous change in local transport conditions.

Once one defines what constitutes a jurisdiction empirically (for example county or commuting zone) and identifies an appropriate set of instruments, one can impose a functional form (for example log-linear) on the set of structural equations and estimate the parameters of interest. These coefficient estimates can shed light on the exact relationships between local transport services and the prevailing urban equilibrium, measured via factor prices and employment. Moreover, the estimates can resolve the theoretical ambiguity in aggregate urban equilibrium effects and test the industry-specific hypotheses regarding the key mechanisms driving the equilibrium response.

5 Limitations and Possible Extensions

There are a few limitations and possible extensions to this model, which would further complicate the analysis of the urban equilibrium effects of changes in international and domestic transport services, but are unlikely to resolve the theoretical ambiguity concerning the aggregate effects. First, the model assumes that households do not derive any utility from changes in international transport costs and local port services. A frequent assumption in the trade literature, for example, suggests that households may benefit from improved access to greater varieties and that the utility, or location value, derived from this accessibility could be modeled as a function of local transport costs. In fact, this type of setting is a common feature reflected in the assumption of Constant Elasticity of Substitution (CES) preferences, where representative consumers have developed a taste for varieties and would thus prefer the location with lowest access costs, all else equal (see, for example, Krugman 1980; Melitz 2003; Allen and Arkolakis 2014).

Another limitation of the model pertains to the mobility restrictions. Anticipating everyone else's best responses, households and firms chose their location and are then operate/work within the jurisdictional boundaries. Changes in factor prices to exogenous shocks and shifts in employment across industries within a jurisdiction are the primary adjustment mechanisms. The possible effects on trade of goods and services across jurisdictional boundaries are muted by assumption. A possible extension would be the relaxation of this assumption placed on the mobility of labor, goods, and services and instead allowing for complex interactions. The result would be a more complex spatial equilibrium as in Allen and Arkolakis (2014), Albouy and Farahani (2017) or Monte et al. (2018) that explicitly encompasses jurisdictional interactions. As a result, changes in local transport conditions would create spillover effects across jurisdictional boundaries. While the presence of these spillover effects is theoretically muted for the sake of tractability, an empirical analysis based on the estimatable system of equations can explore the potential cross-jurisdiction redistribution of economic activity.

6 Conclusion

Several early reviews of the literature on the economic impacts of public capital investments have pointed to the various shortcomings of the existing research. Gillen (1996), for example, argues that initial estimates may suffer from ad hoc modeling frameworks, the omission of labor market effects, the unexplored complementarity and substitutability of infrastructure, the simultaneity of infrastructure investments and output, the re-distributional spillover effects, and failure to account for adjustments in transport services, private investment and factor prices. While several recent studies have addressed a variety of these issues in a convincing manner (Haughwout 1996; Fernald 1999; Chandra and Thompson 2000; Cohen and Paul 2004; Duranton and Turner 2012; Allen and Arkolakis 2014; Möller and Zierer 2018; Monte et al. 2018), this work is the first to model these issues while capturing the intensive margin effects of changing infrastructure utilization, rather than the extensive margin effects of its provision.

The theory provides a multi-sector urban equilibrium model integrating domestic and international transportation and can be interpreted through from the lens of a port-city economy. The model lends itself to evaluate the urban equilibrium effects of changes in domestic and international transport services, such as changes in international trade flowing through the local port of entry or exit. It reiterates the simultaneity between trade, transport, and the local economy and cautions empirical research to consider the full set of structural responses to a change in trade or transport. A change in international transport conditions, for example, is shown to not only influence employment, but also factor prices, which in turn create a feedback effect on employment. Moreover, the theory highlights the industry-specific mechanisms through which changes in transport conditions influence the urban economy and demonstrates that responses systematically vary across sectors. Finally, the theory gives rise to a estimatable system of structural equations that can guide future econometric analysis to properly identify and estimate the illusive effect of port infrastructure utilization - rather than infrastructure investment.

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