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Urban growth, transportation and the spatial dimension of the labour market: A note*

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Abstract. Recently, Duranton and Turner estimated the impact of interstate highways on the average growth of US cities between 1983 and 2003. By estimating a structural model, one of their striking points is that increasing a city's initial stock of highways by 10 per cent leads to a 1.5 per cent positive respond of the city's employment over the sample period. This note mainly argues that their investigation leaves out potential spillovers of labour input from neighbouring growth centres/cities in the steady-state directly implied by the open city assumption. More specifically, this contribution readily extends Duranton and Turner's work by a general equilibrium effect induced by the urban system's labour market fluctuations which is a direct consequence of the open city assumption.

JEL classification: C36, R11, R15, R23, R40, R42

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1 Introduction

Recently, Duranton and Turner (2012) estimate the impact of interstate highways on the average growth of US cities between 1983 and 2003. By estimating a structural urban model for US cities, which implicitly controls for the so-called backwash/polarization effect mainly propagated by Myrdal (1957), one of the author's striking points is that increasing a city's initial stock of highways by 10 per cent leads to a 1.5 per cent positive respond of the city's employment over the 20 year sample period.

This note mainly argues that this investigation leaves out potential spillovers of labour input from neighbouring growth centres/cities in the steady-state directly implied by the open city assumption. The omission of these spillover effects induced by a labour market's general equilibrium effect – directly in line with Hirschmans's (1957) spread/trickle-down effect – might lead to biased estimates as shown in this contribution.

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The structure of this paper is as follows. In the next two sections we present Duranton and Turner's model in a reduced form as well as our extension and reinterpretation of their set-up. Section 4 discusses the main results and Section 5 concludes.

2 The model proposed by Duranton and Turner

This section is primarily concerned with the presentation of the urban growth model outlined in Duranton and Turner's contribution. This should help the reader to follow the later mentioned extensions of the model more easily.

2.1 Basic elements of Duranton and Turner's model

Duranton and Turner consider a simple urban-county model to explain the evolution of roads and employment for a given system of cities. They start with a standard utility function for a representative resident of city i, which reads as:

$$U(A, C, X, L)_i = \frac{AC^{1-\alpha-\beta}X^{\alpha}L^{\beta}}{\alpha^{\alpha}\beta^{\beta}(1-\alpha-\beta)^{1-\alpha-\beta}}, \tag{1}$$

with α and β as the shares of transportation in expenditure and land in expenditure, respectively. A stands for the quality of amenities, C for the consumption of a numéraire good, X represents the travelled distance and L stands for the consumption of land.

Together with the resident's budget-constraint $w = C + pX + qL$,[1] solving the static optimization problem leads to the indirect utility function V:

$$V = \frac{Aw}{p^{\alpha}q^{\beta}}. \tag{2}$$

Next, Duranton and Turner impose that the costs of driving p are an increasing function of a total distance travelled and further decrease with an increasing or tighter network of works. To capture this idea, the price function reads as

$$p = R^{-\delta}(NX)^{\delta}, \tag{3}$$

with R as the road network and NX as the aggregate vehicle travel in the city. δ represents the elasticity of unit transportation costs to road provision.

Further, Duranton and Turner specify the supply of land L to the city to close the model. More specifically, they argue that the supply of land is not limited with respect to its availability but rather limited with respect to the willingness to live far from the city's centre. Thus Duranton and Turner arrive at

$$L = bX^{\phi}, \tag{4}$$

to capture this idea. ϕ stands for the land supply elasticity.

Additionally, they control for the fact that production in the city is affected by agglomeration. To be more precise Duranton and Turner assume that residents' earnings $\underline{w}$, directly connected to a city size of 1, increase with the city's employment. Hence, the evolution of the

[1] p is the price of land, q is the driving costs and w represents the nominal wage rate.

wage rate w can be formally written as

$$w = \underline{w}N^{\sigma}, \quad \sigma > 0. \tag{5}$$

σ represents the strength of agglomeration tendencies. $\underline{w}$ represents the rural, nominal wage rate.

2.2 *Steady-state of Duranton and Turner's model*

As mentioned above, Duranton and Turner's major point is to derive an equation which directly links a city's employment N with the network of roads, R. Assuming that workers from outside the city receive utility $\underline{U}$, and, further assuming that utilities equalize over the entire population defined as inside and outside city's population, together with an equilibrium in the land as well as in the travel market, the (static) equilibrium level of a city's employment level N^* depending on R reads as:

$$N^*(R) = \left[\underline{U}^{1+\delta} \left(\frac{\beta \underline{w}}{b} \right)^{\beta(1+\delta)} \underline{w}^{1+\delta} \underline{(\alpha w)}^{\alpha\delta - \phi\beta} R^{-\delta(\alpha+\phi\beta)} A^{1+\delta} \right]^{-\frac{1}{\Psi}}, \tag{6}$$

with $\Psi \equiv a\delta(1 + \sigma) - \phi\beta(\sigma - \delta) + \sigma\beta(1 + \delta) - \sigma(1 + \delta)$.

2.3 *Adjustment towards equilibrium*

Bearing in mind the adjustment path towards a city's employment equilibrium, Duranton and Turner impose a dynamic structure on their model by capturing the fact that a local economy's employment level N is constantly adjusting to its equilibrium level $N^*(R)$. As consistent with the relevant literature (e.g., Boarnet 1994; Feser and Isserman 2005; and Ke and Feser 2010), Duranton and Turner express the adjustment path of a city's employment level as:

$$N_{t+1} = N^*(R)_t^{\lambda} N_t^{1-\lambda}, \quad \lambda \in (0,1). \tag{7}$$

Further, defining

$$N^*(R) = E_t^{\left(\frac{1}{\lambda}\right)} R_t^{\left(\frac{a}{\lambda}\right)} \tag{8}$$

with

$$E_t \equiv \left[\underline{U}^{1+\delta} \left(\frac{\beta \underline{w}}{b} \right)^{\beta(1+\delta)} \underline{w}^{1+\delta} \underline{(\alpha w)}^{\alpha\delta - \phi\beta} A^{1+\delta} \right] - \frac{\lambda}{\Psi} \quad \text{and} \quad a \equiv \frac{\lambda\delta(\alpha + \phi\beta)}{\Psi},$$

we finally arrive at

$$N_{t+1} = E_t R_t^a N_t^{1-\lambda}. \tag{9}$$

λ in this context represents the speed of a city's labour market adjustment to its steady state employment. Further, a measures the labour market response of a city i due to a city's road-network increase. It is worth noting that in particular the estimate of a is of central importance for Duranton and Turner's obtained results and policy implications.

Estimation equations In this section we briefly present the two-dimensional system of equations of Duranton and Turner's model relevant for their empirical investigation. The first equation, which describes the evolution of the employment level for a given city i, can be directly obtained from the afore derived results: Taking logs[2] of Equation (9), and, further adding an idiosyncratic random shock ε_{1it}, we arrive at

$$\Delta n_{it+1} = ar_{it} - \lambda n_{it} + e_i + \varepsilon_{it}, \tag{10}$$

with $\Delta n_{it+1} \equiv n_{it+1} - n_{it}$.

The second equation describes the evolution of the stock of roads R at time $t+1$. *Ad hoc*, Duranton and Turner assume that R_{t+1} depends on the stock of roads as well as on a given non-equilibrium employment level N_t determined at time t. Further, by introducing the term m_i, Duranton and Turner control for city specific characteristics regarding the stock of roads. By adding an idiosyncratic random component ε_{2it}, we finally obtain

$$R_{it+1} = \exp[m_i + \varepsilon_{2it}] R_{it}^{1-\theta} N_{it}^{\eta}, \tag{11}$$

with $\theta, \eta \in (0,1)$. θ represents the road adjustment and η stands for the elasticity of current roads to past employment. Once again, taking logs from Equation (11), we directly arrive at

$$r_{it+1} - r_{it} = -\theta r_{it} + \eta n_{it} + m_i + \varepsilon_{2it}. \tag{12}$$

Equation (12) together with the expression (10) defines Duranton and Turner's structural model. Due to the fact that n_{it} as well as r_{it} are endogenous variables, ordinary least squares (OLS) estimates are biased. Consequentially, Duranton and Turner introduce a vector of instruments z_t to resolve the addressed problem of endogeneity. Reading their contribution, Duranton and Turner tell a plausible story for each of their instruments to be valid. Based on their estimates, the authors recover parameter values for α, β, δ, λ, η, θ, σ, ϕ and the rural wage $\underline{w}$. *Inter alia*, Duranton and Turner find that a 10 per cent increase of the highway-network kilometres results in a 1.5 per cent positive labour market response after 20 years.

3 Proposed modification

3.1 Preliminary comments

Duranton and Turner (2012, p. 5) state that 'we suppose that all workers in the countryside receive utility $\underline{U}$ and that cities draw their new workers from this rural pool. This is the standard open city assumption. In our application it implies that we may look at changes in one city while holding other cities fixed (rather than treating all cities as part of an interconnected system). This allows us to treat the city as the unit of observation in our empirical work and in our welfare analysis'.

Technically, the open city assumption implies that utility of the entire population remains constant, but population does not because of commuting. It is further an appropriate approximation for the investigation of long-run effects leading to rather dramatic changes in a city or a system of cities. The question now arises is whether this assumption is necessary for Duranton and Turner's set-up. Suppose for a moment that a city adds a new highway to its existing stock of highways R, which in turn reduces travelling costs, for example, p decreases. Given this public investment will attract people from other cities or growth centres, the open city

[2] Lower case letters denote the natural logarithm of a variable, e.g., $x \equiv ln(X)$.

assumption seems to be more accurate than the closed city assumption (e.g., McDonald and McMillen 2010, p. 105). However, believing in the open city assumption, we congruously observe a slight caveat of Duranton and Turner's argumentation: given the open city assumption is appropriate, this implies commuting and as a consequence of that we have to treat all cities/growth centres as interconnected in terms of an interconnected labour market.

If we read this excerpt carefully, we may primarily conjecture that Duranton and Turner assume that cities or growth centres benefit from countryside workers. This conjecture is in line with the so-called backwash/polarization effects mainly popularized by Myrdal (1957) who argued that growth centres characteristically benefit from the less developed areas or cities and hence leaving those worse off in terms of economic development. From this point of view, we may agree with Duranton and Turner's assumption holding other cities fixed.

However, focusing solely on these backwash/polarization effects seems not sufficient in describing the interplay of complex urban systems. From Hirschman's (1957) point of view, economic activities from so-called pole centres spill over to less growth areas or cities resulting in a creation of wealth not only for the less developed areas but also for the growth centre itself. If this so-called spread/trickle-down effect – supporting the interconnectedness of cities – is also relevant, the question arises if it is sufficient to focus solely on the changing characteristics of one city leaving the others not studied. Hence, to answer this question we should refer to the relevant literature to provide an informative basis to find out which of these effects is relevant.

Reflecting the relevant literature, there is ample evidence for the relevance of both effects. Benefiting from new developments in spatial econometric methods, Boarnet (1994) found significant and positive spillover effects of employment growth on a municipal level. Henry et al. (1997) have tested for a combination of both effects, called the spread-backwash hypothesis. For functional US economic regions they found a mix of a spread/trickle-down and backwash/polarization effects leading directly to growth effects in urban core and fringe regions traced back to growth effects from the hinterland. The study of Feser and Isserman (2005), which is from a methodological point of view similar to those conducted by Duranton and Turner, concludes that employment growth in urbanized regions generates spread effects on nearby rural regions and employment in mixed regions causes backwash effects for the hinterland. Further they found that the importance of spillover effects decreases with increasing distance. Ke and Feser (2010) in a recent study support the hypothesis that a combination of both effects is relevant.

From an econometrician's point of view, the ignorance of one effect, although relevant, directly causes inconsistent parameter estimates. Hence, inspired by the relevant literature, this note suggests a straightforward way to expand the model proposed by Duranton and Turner to capture both effects as will be shown in the next section.

3.2 Proposed expansion of Duranton and Turner's set-up

Inspired by the afore mentioned literature, the equilibrium level of employment of the *i*th city can be alternatively interpreted in log-notation as (see Ke and Feser 2010):

$$n_{it}^{**} \equiv f(n^*(r)_{it}, \underline{n}_{it}) = \xi_1 n^*(r)_{it} + \xi_2 \underline{n}_{it}, \quad (\xi_1, \xi_2) \in (0,1), \tag{13}$$

where ξ_1 represents the strength of the backwash/polarization effect indirectly influenced by the agglomeration term σ. Further, ξ_2 replicates the strength of the spread-effect caused by neighbouring labour market effects. $\underline{n}_{it}$ can be interpreted as a spatial lag of the endogenously given employment variable capturing labour market fluctuations of neigbhouring cities.

Starting with Equation (13) which is supported by the relevant literature, it is straightforward to arrive at an equation similar to those given by Equation (10). Rewriting Equations (7) and (8) in log-form, we obtain

$$\underline{n}_{it}^{*} = \frac{1}{\underline{\lambda}}\Delta\underline{n}_{it+1} + \underline{n}_{it} \tag{14}$$

and

$$n_{it}^{*} = \frac{1}{\lambda}(e_i + ar_{it}). \tag{15}$$

At the end of the day, we arrive at

$$\begin{aligned} \Delta n_{it+1} &= \lambda(n_{it}^{**} - n_{it}) \\ &= \lambda(\xi_1 n^*(r)_{it} + \xi_2 \underline{n}_{it}^{*} - n_{it}) \\ &= \xi_1 e_i + \xi_1 ar_{it} + \xi_2 \lambda\left(\frac{1}{\underline{\lambda}}\Delta\underline{n}_{it+1} + \underline{n}_{it}\right) - \lambda n_{it} + \varepsilon_{it}. \end{aligned} \tag{16}$$

Following Duranton and Turner, in the last line of equation (16) we have added an idiosyncratic error component.

Equation (16) is the striking point this contribution makes, and hence, deserves some comments. First, it is rather obvious that an ignorance of the spread/trickle-down-effects depicted by the term $\lambda\left(\frac{1}{\underline{\lambda}}\Delta\underline{n}_{it+1} + \underline{n}_{it}\right)$ yields biased parameter estimates, given it is statistically significant. Second, conducting a simple test of the null-hypothesis ($H_0 := \xi_2\left(\frac{\lambda}{\underline{\lambda}}\right) = 0$) indeed would help to answer the question whether the model of Duranton and Turner is correct, that is, only focusing on one city and neglecting the interconnected labour market dynamics of bordering cities.

The next section is mainly concerned with answering the question which econometric method is appropriate estimating Equations (16) and (12) simultaneously.

3.3 Econometric issues

As known from the relevant spatial econometrics literature, $\underline{n}_{it}$ can be interpreted as a spatial lag of the endogenously given employment variable and, thus, reads as

$$\underline{n}_{it} = \mathbf{W}_{it}\mathbf{n}_t, \forall t, \tag{17}$$

with $\mathbf{W}$ treated as a $(k \times k)$ row-standardized spatial weight matrix [3] with $\mathbf{W}_{it} = [w_{i1t}, w_{i2t}, \ldots, w_{ikt}]$ row elements for $i = \{1, \ldots, k\}$ cities. $\mathbf{n} = [n_1, \ldots, n_k]'$ is a $(k \times 1)$ vector of the neighbouring city's employment levels. Without loss of generality, we assume $\mathbf{W}_{it} = \mathbf{W}_i, \forall t$.

As mentioned before, Duranton and Turner adequately show that their employed set of instruments z_{it} is valid. However, if we refer to equation (16) it is easy to see that given the spread/trickle-down does not vanish, an additional instrument is needed ensuring estimates to be

[3] The diagonal elements of $\mathbf{W}$, w_{ii} are treated as zero. Further, $w_{ij} \neq 0$, for $i \neq j$, which represents two spatially interacting neighbour relations between a city i and city j.

consistent, because the additionally added, spatially-lagged endogenous variable $\Delta \underline{n}_{it+1}$ appears on the right-hand side of equation (16). Ignoring this spatially-lagged endogenous variable, OLS as well as non-spatial IV-estimates are biased because of the fact that

$$\begin{aligned} cov(\Delta \underline{n}_{it+1}, \varepsilon_{it}) &= E\left(\sum_{j=1}^{k} w_{ij} \Delta n_{jt+1} \varepsilon_{it} \right) \\ &= E\left[\sum_{j=1}^{k} w_{ij} \left(\xi_1 e_j + \xi_1 ar_{jt} + \xi_2 \lambda \left(\frac{1}{\underline{\lambda}} \Delta \underline{n}_{jt+1} + n_{jt} \right) - \lambda n_{jt} \right) \varepsilon_{it} \right] \\ &\neq 0. \end{aligned} \tag{18}$$

The intuition of expression (18) is easy to tell. The summation on the right-hand side of equation (18) includes the spatially weighted neighbouring labour market effects for the *i*th city, whereas the *i*th city is not included ($w_{ii} = 0$). Further, a given neighbouring city *j*'s spatial lag change of employment $\Delta \underline{n}_{jt+1}$ must contain Δn_{it+1}. Due to the fact that $E(\Delta n_{it+1} \varepsilon_{it}) \neq 0$, it directly follows that $E(\Delta \underline{n}_{it+1} \varepsilon_{it}) \neq 0$.

Hence, this spatially autocorrelation pattern together with the classical endogenous bias has to be appropriately captured by the applied estimation method. As suggested by the relevant literature, the generalized method of moments estimator proposed by Kelejian and Robinson (1993) tackles this problem satisfactorily by producing consistent estimates.

4 Discussion

First of all, it is worth noting that the main intention of this contribution is clearly focused on making a theoretical point regarding the adequate estimation strategy of Duranton and Turner's model.[4]

This note mainly argues against Duranton and Turner's assumption that each city is small within a large urban system. Instead it argues that changes in a city's road network will affect not just that city, but other cities as well. In particular, it suggests that there could be important spillover effects to neighbouring areas and that this could bias the results.

Hence, the main point of this note is that there could be important spillover effects to neighbouring cities when a city's transportation system is improved, which seems very sensible.

It is worth mentioning that Duranton and Turner try to catch spillover effects in their study by looking precisely into the spillover effects mainly stemming from using the stock of roads in neighbouring metropolitan areas.[5] Conducting a non-spatial IV-regression, they find that the coefficient on the metropolitan area's own roads is essentially unaffected and, further, the coefficient on the roads in neighbouring metropolitan areas is not significantly different from zero, which suggests that spillover effects stemming from roads of neighbouring areas are not significantly different from zero.

But this estimation strategy does not seem sufficient in describing the interplay of complex urban systems. Once again, the open city assumption imposed by Duranton and Turner combines two key elements: first, there is free mobility and, second, each city is small within a large urban system. The second point of course is at odds with the traditional assumption of an open city combined with the existence of growth pools and only valid, if we make the rather restrictive assumption of small and hence homogeneous cities with respect to city size. This assumption

[4] As a consequence of this contribution, the model of Duranton and Turner should be re-estimated in the light of Equation (16). This is clearly beyond of the scope of this note and is left open for a more extended paper.

[5] Refer to Appendix E of Duranton and Turner's contribution.

however does not seem to be appropriate as we have seen from the discussion above regarding growth centres, which directly implies that there exists small and large cities in an open city environment, even in the long-run.

Further, cities are indeed connected, which is an immediate consequence of the open city assumption.[6] McDonald and McMillen (2010, p. 105), point to the fact that 'suppose a city adds a highway that makes commuting less costly. Will this investment attract residents from other cities? If it does, then an open city model may be the right assumption'. Hence, changes in a city i will affect other cities $j \neq i$ in the entire urban system. The framework used by Duranton and Turner definitely corresponds to this long-run open city assumption: for example, improving a road in a city i makes it more attractive relative to other locations and brings in population from elsewhere. The inflow of population increases density. But this happens in every large city in the entire urban system at the same time.

In Duranton and Turner's words, the inclusion of a neighbouring stock of roads only captures the spillover-effect stemming from the usage of neighbouring roads but leaves out the spillover induced by growth effects from neighbouring regions in a complex open city environment. This first effect can be treated as a partial equilibrium effect, the latter readily extends Duranton and Turner's work by a general equilibrium effect induced by the urban system's labour market fluctuations, which is shown by Equation (16) of this contribution.

Based on the derived theoretical results, the question arises how this note's extensions actually change the main critical result obtained by Duranton and Turner, namely, that increasing a city's initial stock of highways by 10 per cent leads to a 1.5 per cent positive respond of the same city's employment over the observed sample period. First, it has to be mentioned that we find several prominent examples of growth zones to which the assumptions presented in this study can be directly applied. Starting with Silicon Valley or the greater Boston area, followed by the greater Munich area, the Wuhan eight-city economic circle (China), the Taiyuan urban economic zone in Shanxi (China), or as analysed in a recent study pushed forward by Ke and Feser (2010), the so-called greater Central Chinese area[7]. Also some large metropolitan statistical areas, such as Chicago or San Fransico which are included in Duranton and Turner's data set can be directly associated with growth zones. All the aforementioned examples have in common are that these consist of complex heterogeneous and interconnected urban systems. Following the arguments given in this contribution, *inter alia*, these urban systems generate strong spread effects of employment growth on each other (see Equation (16)). This latter conclusion is empirically supported by Ke and Feser (2010) for the greater Central Chinese area, which consists of so-called provincial capitals, prefecture-level cities and county-level cities besides rural counties. Based on the conclusions made by Ke and Feser (2010) and our analysis, we also gain insights into the directionality of changes of the above mentioned, central result derived by Duranton and Turner. Depending on the analysed city level (e.g., county-level vs. consolidated city-county-level), the negligence of significant neighbouring cities' spillover effects directly leads to an over or, respectively, underestimation of a US city labour market growth effect.[8]

5 Conclusion

As noted by Duranton and Turner, public spending for US roads amounts to a total of more than 200 billion dollars on average per year. Hence, the implications of this tremendous public

[6] In reality, it seems to be pretty hard to believe that all cities are small, and further are not interconnected regarding the labour market. What we instead observe are growth pools, such as the prominent examples of Los Angeles or Beijing which are interconnected with smaller cities.

[7] Please note that the authors define the greater Central China as the six official central provinces with four selected western provinces. For a detailed description, please refer to Ke and Feser (2010).

[8] Whether the estimation bias is downward or upward depends mainly on the sign of $cov(\Delta n_{it+1}, \Delta \underline{n}_{jt+1})$.

investment for the evolution of cities and the allocation of roads to growing cities have to be evaluated carefully. Based on a simple urban growth model which implicitly controls for the backwash/polarization-effect, *inter alia*, Duranton and Turner have calculated that increasing a city's initial stock of highways by 10 per cent leads to a 1.5 per cent positive respond of the same city's employment over the sample period of 20 years. Although the analysis of Duranton and Turner is well thought-out, it neglects a possible combination of the spread/trickle-down and backwash/polarization effect, which is confirmed to be empirically relevant from preceding studies. Hence, this contribution offers an intuitive expansion of Duranton and Turner's theoretical model and, further, derives a directly estimatable equation for the labour market evolution of a city *i* similar to those suggested by Duranton and Turner. More specifically, this contribution readily extends Duranton and Turner's work by a general equilibrium effect induced by the urban system's labour market fluctuations which is a direct consequence of the open city assumption.

In a nutshell, it is believed that the interplay of the spread/trickle-down- and backwash/polarization effect could help to render the results obtained by Duranton and Turner more precisely and, additionally, help to improve the policy-makers' decision making in this context.

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Resumen. Recientemente, Duranton y Turner estimaron el impacto de las carreteras interestatales en el crecimiento promedio de ciudades de Estados Unidos entre 1983 y 2003. Mediante la estimación de un modelo estructural, uno de sus puntos llamativos es que el aumento en un 10 por ciento de la red inicial de carreteras de una ciudad se traduce en una respuesta positiva del 1,5 por ciento del empleo de la ciudad durante el período de la muestra. Este artículo sostiene principalmente que su investigación dejó de lado los posibles efectos de spillover de insumos de mano de obra de ciudades y centros de crecimiento vecinos en el estado estacionario que implica directamente la hipótesis de una ciudad abierta. Más específicamente, esta contribución amplía el trabajo de Duranton y Turner con un efecto de equilibrio general inducido por las fluctuaciones del mercado laboral del sistema urbano, como consecuencia directa de la hipótesis de ciudad abierta.

要約: 最近、DurantonとTurnerは、インターステート・ハイウェイが、米国の都市の1983年から2003年の平均成長率に与えた影響を推計した。構造化モデルが示す推計の重要なポイントの一つは、対象期間を通じて、都市のハイウェイの初期ストックが10%増加するとその都市の雇用が1.5%増加したことである。これは、開放都市仮説（open city assumption）に直接的に包含される、近接する定常的な成長の中心部／都市、そうした地域からの労働流入のスピルオーバーが、DurantonとTurnerの研究では考慮されていないことを示すものである。さらに具体的には、開放都市仮説の直接的な帰結である都市システムの労働市場の変動から生じる一般均衡的効果により、DurantonとTurnerの分析を容易に拡張できることを示す。