

**ENDOGENOUS REGIONAL ECONOMIC GROWTH
THROUGH TRANSPORTATION INVESTMENT**

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March 18, 2008

FORTHCOMING IN THE
TRANSPORTATION RESEARCH RECORD

ABSTRACT. In this paper, we demonstrate how one can interpret road improvements as productivity improvements in the transportation services industry. We then translate such economic gains into a general equilibrium context in the case of the Peace Bridge between Buffalo, New York, and Fort Erie, Ontario.

Variables exogenous to the model are (1) measured travel time enhancements to be incurred on the improved link and (2) the forecast value of shipments by each industry's to be moved across it. Using this information we estimate industries' responses to these travel time reductions in terms of direct transportation costs, inventory carrying costs, and the value of failed shipments. Extensive interviews with carriers and producers support the notion that improved travel times encourage producers to extend their market areas and, thereby, increase their production in the short run. To measure production change, we recalibrate a regional input-output model for each shipping industry's productivity improvements and adjust their trade coefficients commensurately. We then compare the economic contribution of the shipments to the economic area around Buffalo before and after the improvement.

We recognize that long-run transportation cost reductions are as likely to occur as reduced costs to producers (rather than as production increases). Nonetheless, we assert that by treating producer benefits strictly as production changes, producers' surplus is more readily measured. Thus, this approach converts the measurable change directly attributable to a transportation investment – travel time savings – into broader economy-wide changes. Moreover these changes in jobs, household income, and taxes can be reported with industry and geographical specificity, often a requirement for valid project-specific evaluations.

INTRODUCTION

The benefits and importance of transportation infrastructure to economic growth have long been recognized. Transportation infrastructure has expanded the range over which goods can be marketed. It has made production and distribution processes more efficient, created opportunities for economies of scale and increased specialization, changed logistic systems and reduced costs. These all benefit an economy's productivity. Nonetheless, some researchers claim that in advanced economies as the geographic landscape has become saturated with interstate highways and other major arterials, new roadways often present a zero-sum game and merely redistribute economic activity rather than generate it anew (1).

Other research has shown that highway infrastructure investments can expand the productive capacity of a region. They can do so both by increasing resources and by enhancing the productivity of existing resources. As an unpriced factor, highway infrastructure can radically influence the use of transportation inputs. These transportation cost declines can reduce the costs of other existing inputs, albeit with some moderation (2). This is because they in turn use transportation services as well, although the share of transportation within their production functions is typically small. Due to the above reasons, in the long run, highway investments may lure resources from other regions. In particular, they can encourage some firms to relocate in order to fully exploit the accessibility advantages transportation investments in a particular region can provide (3), thereby inducing so-called agglomerative effects.

One aspect that has not been addressed well in any literature, let alone that on economic development, however, is the degree to which transportation infrastructure may increase the productivity of individual firms. We do so with an eye toward tracing links from transit times, to reliability, and on to carrying costs in order to see how firms' product demand might increase. In the third section, we present our approach of estimating how regional aggregate demand expands, including how we value the benefits of travel-time reductions. We do so by presenting some of our experience with a proposed expansion of the Peace Bridge—a border crossing between the U.S. and Canada. We then wrap up the paper by summarizing our contribution to the literature. We also present directions for improvements in our current approach and sketch out how it might be extended to identify and evaluate similar productivity advantages for service-providing organizations.

PROMOTING REGIONAL GROWTH THROUGH RELIABLE FREIGHT DELIVERY

Manufacturers have become accustomed to productivity gains in transportation. But these times are nearing an end. The transportation industry may have squeezed all it can out of its industrywide reshuffling in the aftermath of federal deregulation. Moreover, unless something new and unforeseen happens, gains from intraindustry technology changes during the past 20 years have also just about played out. Rail gained with the advent of double-stack container cars and high-capacity aluminum hopper cars. Motor carriers improved by deploying longer, wider trailers (up to 53 feet in length and an additional six inches in width), decreasing empty backhauls, and better power trains as evidenced by an increase in the number of miles per truck.

Now, railroads are out of track capacity and highway congestion has many major transportation firms concerned that they have just about stretched their networks out as far as

possible in order to maintain reliability in light of rising traffic congestion. At the same time, motor carrier productivity may be adversely affected by the new hours-of-service rules implemented by the Federal Motor Carrier Safety Administration in October 2005. Given the strength of the current economy, motor carriers have no choice but to increase labor compensation. Thus, motor carriers are now in the unusual position of increasing their costs in the face of these productivity declines. And all of this without considering the rise in energy prices during the past year. Hence, the transportation industry is being squeezed by a lack of productivity enhancement and manufacturers' expectations based on past experiences with the industry. One source they are looking toward is the large array of highway and bridge investments that federal and state governments have been and are continuing to make.

The interest in these government investments stems from the principal effects of transportation investments on manufacturers—reduced trip times and increased shipment reliability. There is no agreement, however, on precisely how changes in travel times and reliability affect business practice. In particular, there is no standard or generally accepted method for assessing those economic effects distinctly attributable to the change in transportation service. Small et al. (4) tried among other things to find if there is a value placed on the predictability of travel times. They concentrated on the value of transit time during high congestion periods. They concluded from their survey that while transit time and freight costs were important considerations, transit-time predictability was not statistically significant. Weisbrod and Treyz (5) suggested a relationship between travel time reduction and increased production but apparently limit the production benefits to manufacturers of transportation times to those through decreased transportation costs. Weisbrod, Vary, and Treyz (6) mentioned more factors but do not provide an explicit algorithm describing how they might have linked them to enhanced production levels. To make a long story short, the principal limitation of research conducted to date and reported in the literature is the lack of empirical evidence linking changes in transportation service (travel time and reliability) to changes in the production and consumption of goods and services. We expand on this explicitly and considerably here.

While we mention trip times and reliability in previous paragraph as if they were separate matters, transit-time savings translate directly into travel reliability. The relationship between these two dimensions of shipping has become especially poignant in light of the logistical revolution that has transpired during the past couple of decades. The movement toward just-in-time delivery has resulted in smaller inventories and better-coordinated production and transportation activities (7).

As freight-intensive firms make such adaptations, they demand narrower delivery windows from the freight sector. Just-in-time and quick-response delivery systems and technological changes, such as the use of intelligent transportation systems, have reduced the need for traditional stored inventory and in turn brought about cost savings to producers. That is, more reliable travel trends translate to less need for just-in-case or buffer inventories. The result has been a reduced cost of goods and services, which has facilitated both an increase in the producers' profit margins and lower product costs to consumers.

Another aspect of just-in-time delivery is that retail stores can stock a greater variety of products. The more space occupied by fast-moving items the less available is space for items with a lower turnover rate. More efficient transportation facilitates quicker replenishment of the fast moving items, which typically need more shelf space. Quicker replenishment, therefore can

translate into the use of less shelf space for these fast-moving items. This enables the retailer to make larger displays of higher-profit items or of a wider array of products, the latter of which is often found to be a draw to customers. Hence, not only have the information systems that make just-in-time delivery possible reduced inventory carrying costs, but they also have enhanced firms' abilities to improve revenues.

The relationship between reliability and inventory carrying costs cannot be overstated. Golob and Regan (8) note that managers of trucking firms, particularly those with intermodal and refrigerated operations, perceive that the most serious problem associated with highway congestion is unreliable travel times. This is because such firms typically are contracted to deliver product to a location at a fixed time of day. Thus, the possibility of shorter travel times assures that delivery is more likely to arrive within the specified time window—i.e., that the delivery will be reliable. The more reliable or predictable is delivery, the more efficient is the flow and stocking of goods for the receiving firm. This, in turn, improves the overall logistics of the receiving firm (particularly their inventory carrying costs) and, hence, its productivity.

Immediately after the cost of freight movement (including time cost) falls, firms initially maintain the modus operandus, pocketing the difference in costs (9). In the longer run, however, firms alter the way they do business. Some firms respond to the reduced costs by reducing prices with the hope of increasing revenues by selling more goods in their current market; others respond by expanding their market area (9). If cost savings are large enough, however, manufacturers use the benefits of delivery-time savings from road improvements to restructure their entire logistics network—relocating warehouses and/or shutting down less-productive plants. In this way, they reduce their net aggregate costs of production and inventory carrying, perhaps even increasing net transportation costs. Naturally in the face of the large declines in costs gained through their logistics reorganization, firms also often respond by reducing prices to increase the demand for their products and sometimes extending the spatial extent of their market as well.

Thus to divisions and departments of manufacturers that are charged with logistical support, the benefits are both strong and clear. But to the entire firm and following the findings of (2), generally speaking, the benefits of infrastructure-driven logistical enhancements must surely be small. This is largely because manufacturing firms, in particular, typically spend only small shares of their operating expenses on transportation services. Hence, even if the logistical efficiencies captured by firms are large, price reductions that manufacturers' transmit to their customers are typically minute, if they should, in fact, pass on any of the efficiency gains to their customers.

While the upshot of this literature is that some efficiency benefits will be garnered by producers, retailers, and consumers alike, the magnitude of the benefits is not well enumerated. Brief interviews with a few New Jersey producers revealed that the transit savings would have to be substantial (on the order of 20 percent) before they would undertake significant restructuring of their logistical systems (warehouse or plant relocation). This is largely because logistics costs are, as stated earlier, but a small part of their overall product costs. Moreover, most freight movements are under long-term contracts with transportation service organizations. Thus, we would expect some stickiness in freight rates. Thus carriers *would* expect to experience rate declines when their contracts are up for rebid, but only in real terms over the long term.

As suggested in the last two sentences above, travel-time savings enhance the competitive edge of trucking firms by reducing their costs, either through a reduced labor requirement effected by the use of a smaller fleet or the ability to generate more revenue hours by carrying more freight in a given period of time than before the travel time improvements. In some cases, in addition to travel-time savings, new roads can enable the use of heavier trucks, which exaggerates the travel-time effect. Typically some of the resulting cost savings are passed along to customers, to give the trucking firm a pricing edge over its competition. In extremely a competitive trucking environment, which is the case in most urbanized areas, price reductions are expected when the real costs of service (travel time reductions) are evident. Interviews with large manufacturers in the Buffalo region, for example, revealed that the shippers were employing the services of a dozen or more trucking firms continuously bidding on short term hauling contracts.

Alternative to or perhaps in concert with the pricing advantage, some trucking firms choose not to reduce their labor force and instead opt to increase their market reach. To such firms, the time saved in transit translates to more highway miles per vehicle for the same amount of time as before an improvement that induced the time savings. This can often lead to an increase in the size of market area they serve.

To date our interviews with trucking firms regarding their disposition of the travel-time savings have yielded mixed results, with different firms allocating the savings to various alternatives: improved returns to stockholders (profits), equipment investment, freight rate reductions, and market expansion. Most of these options (the first three) should yield productivity enhancements to the users of the goods and services being delivered. We would expect that such productivity should be measured reasonably well by the various studies measuring the effect of highway spending on the productivity of industries in a region. Unfortunately, this literature remains somewhat contentious.

Expansion of the market of trucking firms has no theoretical basis for enhancing other firms' productivities, however. In fact, to our knowledge, this line of inquiry has not been pursued for freight transportation providers. The theory behind market expansion is predicated upon von Thünen-like conditions. That is, it is a reduction of the freight rate that should facilitate an expansion of a market's "frontier." It was with this in mind that we moved forward with our research.

PREDICTING DEVELOPMENT INDUCED BY HIGHWAY INVESTMENTS: THE CASE OF THE PEACE BRIDGE

Tying Buffalo, New York, to Fort Erie, Ontario, the Peace Bridge has become the second largest single crossing between the United States and Canada (behind the Detroit area's Ambassador Bridge).. Interestingly, since the bridge links the Queen Elizabeth Way (QEW) in Canada to the New York Thruway, much of the value of freight crossing over the Peace Bridge is due to movements between the Northeastern and Midwestern regions of the US. The movements take this route to avoid the extra distance and time it would take to circumnavigate Lake Erie. Moreover, all but one alternate bridge in the immediate vicinity (i.e., the Rainbow Bridge, which is even nearer capacity than the Peace Bridge) are closed to freight traffic. We estimate the value of trade across the Peace Bridge to be on the order of \$120 billion (FOB manufacturer) annually. This estimate differs significantly from the value of trade reported by

US and Canadian customs for the port of Buffalo/Ft. Erie. US and Canadian customs use only the value of commodities declared at that port, and do not include the value of goods declared at other ports of entry. Further, they do not include the value of shipments from US origins to US destinations, which are significant for movements from the US northeast to the US Midwest that find the route through Canada more cost-effective. Appendix A to this paper documents the procedures used to develop the estimate of value of commodities moved across the Peace Bridge, a rather complicated process converting weights reported in the O-D survey to commodity values and then linked to specific industries.

The Peace Bridge remains virtually the same as it was when completed in 1927 and contains only a single, three-lane span. The center lane is reversible and can be used to ease congestion during peak travel conditions. The Directors of the original Buffalo and Fort Erie Public Bridge Company could not have anticipated the economic and population growth of the two countries, nor could they have foreseen the tremendous increase in tourist and commercial traffic achieved over the past 30 years. Yet, until lately, the capacity of the original bridge had been able to accommodate most traffic increases. In response to growing traffic – fueled by expanding trade between the US and Canada – from 1992 to 1999 the Buffalo and Fort Erie Public Bridge Authority examined various ways to expand the capacity of the Peace Bridge.

Exogenous Data: Travel Times and Freight Movements

Table 1 shows some results of a traffic study of the Peace Bridge performed for the Federal Highway Administration by Battelle Memorial Institute (11). It reveals that by 2001 congestion at the Peace Bridge had begun to reach abysmal levels during much of the day. The baseline time is the number of minutes needed to traverse the Peace Bridge (between the starting point in the queue to customs in the outbound country and through the inspection point in the inbound country) under free-flow traffic conditions. The table shows that average travel times in both directions on the Peace Bridge had reached twice that of the baseline. Interestingly, while the average travel time is similar in both directions, reliability favors traffic leaving the U.S. This is observed by examining differences in the 95th percentile times. (The 95th percentile time is the time within which 95 percent of all trucks can cross the border.) These extreme delays have been variously attributed to international border processing staffing and the physical layout of processing facilities, and to capacity limitations of the Peace Bridge itself. Because of this, most expansion plans for the Peace Bridge included a particular focus on the plaza that handles traffic entering the US.

<Table 1 about here>

We were fortunate to have access to the 1999 Canadian National Roadside Survey, a comprehensive O-D survey produced by the Canadian Council of Motor Transport Administrators (12). (See Appendix A for more on the tribulations and disappointments we experienced in the course of applying this data set. The data were, of course, the most recent statistical source available at the time we performed the study.) It enabled us to identify the extent to which specific commodities traverse the Peace Bridge by geographic location. The level of commodity detail identified in this data set was important to our analysis. This was because we used proposed travel time improvements from the expansion of the bridge to estimate decreases in costs incurred by industries in a regional input-output model with about 500 sectors

The model we used was a multi-regional input-output (MRIO) model produced by Rutgers Economic Advisory Service (R/ECON™). R/ECON™ input-output models (see *12* for documentation) descend directly from the Regional Science Research Institute's PC I-O model tradition that has been documented in (*13, 14, and 15*). The R/ECON™ I-O model underlies the current version of the MARAD PortKit and of the economic impacts analysis performed in TELUS, which is the transportation, economic and land use model funded by U.S. Department of Transportation for metropolitan planning organizations.

The Peace Bridge provides perfect test ground for our approach since industries now using that congested link—from both the US and Canada—are largely a captive market for the purposes of our analysis. That is, the exercise is largely uncomplicated by concerns about the effects of diversions to alternative links and paths which are considered to be at or near the capacity constraints of the Peace Bridge based on traffic studies done by others. Similarly, we opted not to identify the value of foregone freight traffic—goods not shipped as a consequence of increased congestion in the absence of improvements to the bridge—as some prior studies of border crossings have done (see, e.g., *16, 17, and 18*). The reason we didn't was because we had observed that these studies assume existing freight movements cease when the volume/capacity ratio exceeds some level (typically 1.1) and measure this loss at the wholesale value of the goods shipped. The cessation of certain freight movements and the assumption that these resulted in production losses (loss of market share) for affected industries was the principal measure of economic costs. Hence, instead, we reduce manufacturers' transportation service costs using the proposed travel-time improvements.

A Comparative Statics Approach to Measuring Industry Efficiency Improvements

In our example, we measure the impact of improving the Peace Bridge by examining the effects on Metropolitan Buffalo only. Moreover, we do so by measuring the economic contribution of shipments across the bridge in one direction only—from the U.S. to Canada. Clearly a more comprehensive approach should be taken. Not only should shipments in both directions be measured but also the values of journeys to work and shopping trips. This work was done for the DEIS submission (unpublished at the writing of this paper) for the Peace Bridge Expansion Project, also prepared by the paper authors. Evaluation using the R/ECON™ I-O model of outbound shipments from Canada would have been somewhat problematic, however, because results from the Canadian equivalent do not match well with those reported by U.S. regional input-output models in general.

In any case, we start out, as mentioned earlier by identifying bridge-based flows of shipments originating in metropolitan Buffalo. We next estimate the net reductions in transportation costs for each metro Buffalo-based industry induced by the proposed bridge improvements—so-called “partial equilibrium effects.” Naturally these are the cost reductions that will have been obtained compared to the absence of any improvements. That is, we suppose that congestion will increase beyond the present situation. Using these cost-reduction estimates, we presume that in the short-run, the manufacturers will increase their production by the amount of the transportation cost reductions, rather than increase profits. We then estimate the general equilibrium effects of the assumed production increases. We do so using a multiregional input-output model focused upon the Buffalo metropolitan area. Details of the model formulation follow.

Essentially the changes to the model are two-fold. We alter regional production functions to reflect the transportation efficiencies, and we alter the region's size to reflect the greater

spatial extent of Buffalo manufacturers' market due to improved transportation efficiency provided by the bridge. Moreover, we make sure to improve the efficiency of those industries by the share of the regional industry's shipments that presently cross the bridge. The technical manner in which we effected these alterations is detailed in Appendix B.

In modifying the production functions in the input-output model, we do so only for industries that ship goods across the Peace Bridge. In particular, we adjust the relative productivity improvement of the trucking industry by reducing its share of inputs in the relevant manufacturing industries.

Since a change in the average travel time to traverse the region, affects the region's size, we expand the region by the average travel time savings attributable to the improvement of the Peace Bridge times an average interstate highway speed of 50 miles per hour.

Estimating Manufacturers' Cost Savings

In our approach, foregone production costs include shipments that do not arrive as scheduled which affects an industry's inventory carrying cost (to allow for production when shipments do not arrive to meet production schedules). To these savings in inventory carrying costs we add the value of reduced carrier charges to reach current and prospective geographic markets. We start out the exercise by estimating the hourly value of production for the industries shipping goods across the Peace Bridge. Hence, given the value of the shipments, for each industry we estimated the share of that value allocated as gross domestic product by industry, "gross state product" as the state level, or as "value added" in national accounts. We then divided this by the number of establishments and then, again, by 3,000 hours—our estimate of the number of hours that a typical manufacturer operates each year. After weighting by commodity traversing the Peace Bridge in 2002, we estimated the value of production crossing the Peace Bridge to average about \$6,700 per hour. Our formula to estimate the incremental production based on improved reliability (inventory reduction) and productivity gained by reduced transit costs attributable to the travel time savings is:

$$\Delta x = \sum_i (x_i^1 - x_i^0) = \sum_i \left(\frac{v_i}{h_i} \Delta f_i + t_i \right) h_i^s$$

Where Δx is the change in the total value of shipments,

v_i is the amount of annual inventory held for commodity i ,

h_i is the annual hours of operation required to produce x_i^0 ,

Δf_i is change in the annual failure rate for deliveries ($f_i^1 - f_i^0$),

t_i is the hourly charge for transporting commodity i , and

h_i^s is the annual hours of travel time saved in transporting commodity i due to the investment.

On a spreadsheet, we then tested various hypotheses for the failure rate (0.5% to 1.5% of all shipments according to industry estimates); for hourly values of production on the margin versus average proportional inventory cost savings (25 to 50% of total production costs), and for hours of inventory used or production foregone per undelivered shipment; and hourly costs of transport (\$70 to \$100). As a result we found that the cost of congestion ranged between \$132 and \$171 per hour with an average of \$148.

Prior studies of the economic effects of border crossings relied on hourly transport costs derived in (7). That study used stated preference surveys of a small number of freight carriers to derive an estimate of \$144 to \$193 per hour for normal travel time, and \$371 per hour for delay time under severe congestion conditions. This analysis used hourly carrier costs derived from the Census of Wholesale Trade, a survey of shippers and carriers in the Buffalo/Ft. Erie regions, and independent studies done by NYSDOT and others to estimate the average per hour carrier cost to producers. Costs derived in this manner range from \$70 to \$100 per hour and represent actual costs to producers rather than cost “presumed” by carriers. Most prior studies of the effects on business sales, jobs, and household income attributable to changes in transport service have, in our judgment, mistakenly used the NCHRP costs plus forgone production costs to derive the dollar value of congestion. The average value of carrier charges plus reduced production costs (see prior paragraph) used in this analysis is \$148 (US) per hour. This estimate is specific to the industries moving goods across the Peace Bridge.

ECONOMIC EFFECTS ON THE BUFFALO REGIONAL ECONOMY

Using the estimate of change in RPCs from the I-O model expansion, plus the calculated increases in production attributable to the productivity gains from reduced transportations costs, Table 2 shows our estimate of total economic effects (not just the direct effects) on the Buffalo regional economy from an estimated 30-minute average travel time savings for the shipment of commodities produced in the Buffalo region and transported across the Peace Bridge. (In the Final EIS for the Peace Bridge, which at the time of writing this piece is not complete, we will use the average trip and aggregate vehicle hour savings estimated for trucks from the project’s traffic modeling consultant, Wilbur Smith Associates. The traffic model should account for diversions and other full network effects in computing time savings for the Peace Bridge crossing itself.) We understand that the 30-minute delay we apply here is incongruent with the findings of the Battelle (11) study, which was dated even at the time of our own analysis. At the writing of this paper, travel time and delay estimates under future design-year conditions were still being developed by others, with preliminary indications that delays in the foreseeable future may exceed by several orders of magnitude those experienced today. Hence, we used an estimate of delay under design year conditions that we thought would be both reasonable and from which any results could be readily interpolated once an actual time of delay is established. Indeed, all calculations in this piece are perfectly unitarily linear with respect to the amount of delay.

<Table 2 about here>

As data in Table 2 indicate, the effects on regional output and employment are predictably modest. Increasing production within industries in the Buffalo region that currently ship goods across the Peace Bridge is expected to expand the total general equilibrium value of regional shipments by about \$120 million annually—a 1.2% increase over the base case for the affected industries. Similarly, regional employment is estimated to expand by about 800 jobs, a 1.3% increase over the base case for the affected industries. We have not considered “threshold” effects in this general formulation— those circumstances in which congestion delays over a certain time or reductions in the reliability of shipments might render a particular industry non-

competitive. In actual project evaluations, these are and have been taken into consideration by surveying the affected firms.

SUMMARY AND IMPLICATIONS FOR FURTHER RESEARCH

In the real world of transportation project planning and evaluation, the notion of change that is “induced by and attributable to the proposed action” is endemic to presentation of project alternatives in the agency and public review process, and is further codified in US Federal Court precedents for review of environmental documents (EISs). Evaluations that are context specific to the regions in which the proposed transportation is made are vastly preferable to inferences drawn from other regions. The principle advantage of this approach for project evaluations, therefore, is that it converts the measurable change directly attributable to a transportation investment – travel time savings – into a straightforward hypothesis for change in business output, jobs, household income, and taxes. It is also industry and geographically specific.

This model of individual firm response to a context specific change in travel times may suggest why it has been so difficult to capture transportation efficiencies using surrogate measures of travel time savings, such as lane miles of new highways, average speeds, construction values, and so forth – not all industries or locations within a region benefit directly from a specific transportation project investment, and change measured in a regional context may be quite small for most contemporary highway investments. Further research is needed to determine under what conditions, such as local labor force skills or availability, local land costs and taxes, and so forth, firms may be unable to expand output in response to the productivity gains from travel time savings. The disadvantage of this approach, therefore, is that it may account for the “utility” of the transportation investment without measuring actual firm behavior. Unfortunately, all other approaches to this problem share a similar weakness. Empirical tests may be difficult, since a backward look at travel times prior to a transportation improvement would require not only ex ante commodity origin and destination data, but also a recalibration of regional traffic models to the prior period travel time conditions. In our case, if the Peace Bridge Expansion Project is undertaken it will be interesting to revisit via a new origin-destination survey the movement of commodities we would project to increase as a consequence of productivity gains through reduced travel times.

Another potentially promising line of research implied by the methodology reported herein relates to the value of travel time savings to services industries. In the case of the services and financial sectors, both geographic accessibility to a regional labor force and time spent by employees commuting have long been recognized as important variables to productivity within services industries (freight movements are of minor consequence compared to manufacturers). Prior research has attempted to measure gains to employers in the form of reduced labor costs following transportation investments that can change commuting times or the effective reach of firms to a regional labor force. Some research has, incorrectly, hypothesized that workers actually gain income from reduced travel times. Our approach suggests that potential gains in productivity to the services industries are more important than labor costs per hour, and that gains in worker productivity (reduced commuting stress, personal utility gained from less commuting time, and so forth) might be better measured from the perspective of the employing firm. Some interesting work along these lines has been reported by Luskin and Chandrasekaran (19), who derived a measure of the hourly value to employers of congestion imposed by an interchange reconstruction in North Dallas, Texas. The resulting value was higher than the

average hourly wages paid to employees. In our approach, we might hypothesize that summing these values across the affected industries and assigning them to the industries' potential output (productivity enhancement) could be a measure of the direct effect of the transportation improvement.

APPENDIX A: DEVELOPMENT OF A DATASET FOR ASSESSING FREIGHT IMPACTS

Introduction

This section describes how the Project Team created the baseline dataset used as input in estimating the economic impact on the U.S. (Buffalo MSA, New York State and the US) from commodities trade flowing across the Peace Bridge. The purpose of creating the dataset was to convert the existing data measuring trade importance at the bridge level into a format that was compatible with the structure of the economic input-output model used by Rutgers University's Center for Urban Policy Research.

Method & Source Data Used

The source trade shipment data file was an extract obtained from the 1999 Canadian National Roadside Survey (NRS). The dataset was provided to E&E by Wilbur Smith Inc. to ensure consistency between the Peace Bridge Expansion Project transportation traffic analysis and the economic impact analysis. The NRS data was the only available data that could be used in tandem with other complementary trade data to measure the value of trade shipments at the bridge level. The following procedures discuss how the NRS data was formatted such that estimates of the value of shipments crossing the bridge at a certain level of detail could be made.

The NRS survey contains data on the commodity shipments flowing over the Peace Bridge expressed in kilograms and coded or described by a trade classification called the Standard Classification of Transported Goods (SCTG) five-digit level. The NRS data also contained data on the direction of trade (i.e. Passes Peace Bridge US to Fort Erie and Passes Peace Bridge Fort Erie to US) necessary to understand bilateral trade flow relationships between the U.S. and Canada. Since the NRS survey is Canadian in origin, a database record or sampled shipment marked as passing the Peace Bridge (Fort Erie to U.S) would be counted as a U.S. import and a Canadian export for that particular commodity. Moreover, the data set detailed the state/province and community of both the origin and destination for each shipment.

The SCTG consists of a blend of transportation characteristics, commodity similarities, and industry-of-origin considerations, designed to create statistically significant categories. It is a structured list that is defined at its less-detailed levels according to the Harmonized Commodity Description and Coding System (HS), and at more-detailed levels, according to patterns of industrial activity. Other factors in the definition of categories were transportation considerations such as volume, revenue, value, origin, and destination. SCTG is a Canada-U.S. initiative, designed to provide categories for the 1997 U.S. Commodity Flow Survey (CFS) and to improve the integration of Canadian transportation data, particularly for marine, truck, and rail. The classification is also designed to permit comparison of Canadian and U.S. transportation data. In addition, because of its HS basis, SCTG can be used for other international comparisons. SCTG is an important development in the creation of an integrated system of classification that is used for economic analysis, covering production, shipments, and international trade.

Step 1: Classifying NRS Data by Standard Industrial Classification System Codes

To render the NRS survey data compatible with the input-output model, it was necessary to express or classify this data by the Standard Industrial Classification (SIC) code. The input-

output model required that the value of shipments data be classified by Standard Industrial Classification (SIC) codes. The first step involved was assigning an SIC code to each SCTG-5 commodity code from the NRS survey. The result was a bridge matrix or data concordance table that assigned the appropriate SIC code to the corresponding SCTG-5 code commodity shipment. The U.S. Census Bureau has developed such a data concordance table.

Given the large variety of commodities, some of the NRS data were not covered by the Census Bureau concordance. Consequently some additional manual procedures were performed using the International Harmonized System (HS) trade classifications as an intermediary. That is, a data concordance was obtained by first mapping SCTG to HS codes and then HS codes to SIC Codes. The SCTG to HS concordance was available through Statistics Canada, while the HS to SIC concordance was available through the U.S. Census Bureau. After this classifying procedure was completed, each record within the original NRS survey extract table called “PeaceV” was assigned a 4-digit SIC code.

Step 2: Application of NRS Survey Expansion Factors

The NRS sample survey contains weights that permit analysts to scale up the shipments in the survey to reflect the full weekly volume of all truck-based shipments crossing the bridge. The weight corresponds to the number of truck trips operating on Canadian roads during a one-week period in the summer/fall of 1999 that have truck, driver, carrier, cargo and trip characteristics that are identical to the shipment described by the database record (11). The weighting factor represents all traffic passing through the bridge irrespective of the location where the survey was taken. The product of the weighting factor and the individual trade shipment record is an estimate of the volume of all weekly trade shipments in kilograms.

Step 3: Calculation of Annual Factors and Annual Shipments in Kilograms

Annualized data are required when analysis is conducted using input-output models. Hence, to convert the weekly data from the NRS described above, “annualizing” factors were calculated for each direction across the bridge as follows:

$$\text{Annual Factor (Westbound Shipments (US Exports))} = \left[\frac{\sum 1999 \text{ Westbound Truck Volume}}{\sum \text{Weighted Westbound Truck Trips (NRS Sample)}} \right] = \frac{757,204}{14,559.6} = 52$$

$$\text{Annual Factor (Eastbound Shipments (US Imports))} = \left[\frac{\sum 1999 \text{ Eastbound Truck Volume}}{\sum \text{Weighted Eastbound Truck Trips (NRS Sample)}} \right] = \frac{722,832}{14,948.86} = 43.85$$

Annual shipments in kilograms were calculated by taking the product of the weekly shipments and the annual factor shown above corresponding to whether the shipment was Eastbound or Westbound.

Step 4: Estimation of Unit Values per SIC 4-Digit Code Used to Value Shipment Volumes in Kilograms

Next, the commodities shipments from the NRS survey, originally provided by Wilbur Smith in the data/table called PeaceV2, needed to be converted into dollar values for using data from the input-output model. For this conversion, a separate data table containing the value of trade (imports and exports to Canada) passing through the Port of Buffalo was downloaded and created from the U.S. Census Bureau files. This database contained records originally expressed in HS (International Harmonized System) 10-digit detail level containing both physical quantity measures (count, kilograms, tons, barrels) and corresponding values in dollars (both 2001 US or 2000 US). The data were used to estimate value-to-weight ratios (in US\$/kg). These ratios were used to convert the annualized survey data (in kilograms) to their value in dollars. Since not all of the records within this weight-to-value database were expressed as weights (the measure available in the NRS survey PeaceV2 table) additional steps were taken to convert the various measures of commodity volume in this Census Bureau file into common units.

Values for the year 1999 were estimated using U.S. Import and Export Price Indexes available from the U.S. Department of Labor, Bureau of Labor Statistics. The annual imports Index (all commodities), was used to deflate the year 2000 unit values for imports to express these values in corresponding 1999 dollars. The imports (exports) deflators were calculated in the following manner:

$$1999 \text{ Imports Deflator} = \frac{\text{BLS End Use Imports Index 1999}}{\text{BLS End Use Imports Index 2000}} = \frac{93.91}{100.0} = 0.9391$$

$$1999 \text{ Exports Deflator} = \frac{\text{BLS End Use Exports Index 1999}}{\text{BLS End Use Exports Index 2000}} = \frac{98.42}{100.0} = 0.9842$$

The deflators were applied to all unit value records for the year 2000 to create estimated 1999 unit values. Because the Census data were originally expressed in HS codes, a bridge to convert HS to SIC codes also had to be applied to the data. Because the analysis is based on assigning unit values at the SIC code level, averages were calculated from individual international trade records originally expressed in 10-digit HS (Harmonized System) codes.

Step 5: Creation of Final Table Summaries - Input Files to Economic Impact Model

During the fifth step a unit value was assigned to the corresponding SIC-coded shipment, which was expressed in terms of annual kilograms shipped across the Peace Bridge. The product of the two fields resulted in an estimate of the annual value of shipments for that SIC code. Using the database, one could then sum by SIC code to obtain the value of all shipments (imports or exports) using the Peace Bridge for a particular commodity. Correspondingly, the structure of the database also enabled the user to calculate summaries based on origin and destination pairs (jurisdiction—State or Province—and/or municipality) for a particular commodity. Additional details on the database are available in the project work files and were summarized in the document called ProceduresCommodityValues.doc.

Step 6: Cross-checking and Dataset Modification

Next, we summed across the database to estimate the amount of commodity exported to Canada across the Peace Bridge from locations in (1) the Buffalo MSA, (2) the State of New York, (3) New England (the states east of the State of New York, and (4) the rest of US. These quantities were checked against estimates of the upper bounds for commodity outflows from each of these corresponding regions as estimated in the data in the regional input-output model.

The point of this check was to make sure that the commodity flows did not exceed each region's capacity to produce each commodity.

Regional supplies by industry were derived from the quotient of estimates of regional earnings data estimated and labor income coefficients from the R/Econ national I-O table. (See Lahr (12) for a more through discussion of the approach used in the R/Econ I-O model.) Total regional demand is the sum of this interindustry demand and the demands for industry production placed by regional final demand—i.e., locally based government operations, regional households, and the region's international exports. Multiplying the regional supply estimates up the columns of the national input-output direct-requirements matrix and summing across the rows of the resulting matrix yielded regional interindustry demand. The product of regional output and the national final-demand/output ratio yielded regional final demand by industry.

Next, estimates of the amount of local supplies used to meet local demand were produced. (See techniques discussed in (15) regarding estimation of the so-called "regional purchase coefficient," which when multiplied by commodity demand yields the amount of the local commodity supplied to meet local demand for a commodity.) From this, the region's upper bound for a commodity's export to Canada were identified by subtracting from regional commodity supply the amount of that supply used to meet the region's own local demand.

These upper bounds for commodity exports were next compared to the export estimates based upon the NRS survey. In most cases, survey-based estimates for commodity exports were well within the upper-bound limit. Nonetheless, for certain commodities with an origin in the Erie and Niagara Counties the amount shipped exceeded the upper bound. This was the case for the following sectors: (1) Vegetables; (2) Book publishing; (3) Chemicals and chemical preparations; (4) Tires and inner tubes; (5) Internal combustion engines; (6) Prerecorded records and tapes; (7) Motor vehicles and passenger car bodies; (8) Motor vehicle parts and accessories; (9) Electromedical and electrotherapeutic apparatus; (10) Musical instruments; and (11) Games, toys, and children's vehicles. In all cases, the NRS-based estimate exceeded accounted for in the R/Econ I-O model of the region. There are several reasons why the estimates might not compare. The two most likely reasons are (1) that the point of origin designated in the NRS survey was merely a warehouse rather than a manufacturer and (2) the *commodity* classification obtained during the course of the survey simply did not match the *industry* classification of the Buffalo-based firm that produced it. In any case, the portion of the NRS-based exports that exceeded the estimated export upper bound was either redistributed to other similar industries (the case of commodities attributed to the automotive and chemical industries) or was attributed to production by other regions of the U.S. (the case of the remaining industries).

Appendix B

Technical Details for Calculating Productivity Efficiencies and Market Expansion from Transportation Improvements

As is the case with any detailed input-output model in the United States, ours includes a sector labeled “trucking and warehousing,” which we shall refer to here as the trucking service industry. It is the industry that actually transports goods across the border. We give this industry no special direct productivity benefits, because as we mentioned early we purport that all benefits the industry obtains via transportation infrastructure improvements will be passed on to its customers (at least in the medium run) due to the extremely competitive nature of that industry.

Changing Production Functions to Reflect the Reduced Costs of Trucking Services

As mentioned in the main body of the paper, as a first step we modified production functions only for those manufacturing industries that ship their product across the Peace Bridge. This is done as follows. Let

\mathbf{x} = the vector of total industry shipments

\mathbf{x}^{PB} = the vector of the value of shipments by industry crossing the Peace Bridge

λ_t = the vector of a measure of transportation efficiency (average travel time) by industry without bridge improvements

$\bar{\lambda}_t$ = the same vector with the improvement

so that

$$\Delta \mathbf{t} = \left(\frac{\bar{\lambda}_t}{\lambda_t} \right) \times \left(\frac{\mathbf{x} - \mathbf{x}^{PB}}{\mathbf{x}} \right)$$

where all operations (multiplication and division) are Hadamard (element-by-element). Thus we can denote the change to the trucking services row, t , of the regional technology matrix for the Buffalo metropolitan region, $\mathbf{A} = \{a_{ij}\}$, as follows:

$$\Delta a_{t.} = [a_{t.} - (\Delta \mathbf{t} \times a_{t.})]$$

After renormalization of the columns of the region’s technology matrix, which assures that value added (largely, labor costs and profits) is the same after the transportation improvement as it was without it:

$$\bar{\mathbf{A}}_{\sim t.} = \left(\frac{\mathbf{i}' \mathbf{A}_{\sim t.} + \Delta a_{t.}}{\mathbf{i}' \mathbf{A}_{\sim t.}} \right)' \mathbf{A}_{\sim t.}, \text{ for } i \neq t$$

or

$$\bar{a}_{t.} = (\Delta \mathbf{t} \times a_{t.}) \times \left(\frac{\mathbf{i}' \mathbf{A}_{\sim t.} + \Delta a_{t.}}{\mathbf{i}' \mathbf{A}_{\sim t.}} \right), \text{ for } i = t$$

Note also that the average travel time savings is the weighted average of the elements in the Δt vector.

Altering Regional Purchase Coefficients to Reflect Expansion of Market Area

The region's expanded market capacity is altered via the formulation of the regional purchase coefficients (RPCs), which are used to convert the region's technology matrix into a regional direct matrix by describing each regional industry's propensity for participating interregional trade. RPCs are defined as

$$\rho = \frac{LS}{D}$$

Where LS = the vector of local production (by industry) that fulfills local demand (local supplies) and

D = the vector of estimated local demands by industry.

We estimate the vector of RPCs, ρ , following (15) who used the following formulation for the RPC of arbitrary manufacturing industry i :

$$\rho_i = D_i \left[\left(e^{-1/x_i} \right) - 1 \right]$$

Thus

$$LS = D e^{-1/x}$$

Where

$$x_i = k \prod_{j=1}^n (z_{ij})^{\alpha_j}$$

So that one can estimate the parameter estimates, α_j , of the n different variables explaining local supplies of industry i , z_{ij} ($j=1, \dots, n$), using the following equation:

$$\ln \left[\frac{-1}{\ln(\ln LS_i / \ln D_i)} \right] = \ln k + \sum_{j=1}^n \alpha_j \ln z_{ij}$$

Treyz and Stevens (15) report the key explanatory variables to be local demand, the supply/demand ratio for the industry in the region, the weight/value ratio of the commodity, the region's share of the nation's land area, and the regional industry's establishments per employee compared to the nation's. Clearly, in effecting change in the RPC, we worked on the change in supply and demand as well as in the change in the region's share of the nation's land area. This latter was altered by the additional distance that could be traversed with no bridge-based time delay.

It is important to note that nice property of the above RPC formulation is that it bounds the RPC between 0 and 1. This is its range of the RPC that can be readily established by formal theoretic means.

ACKNOWLEDGEMENTS

The genesis of this paper was a presentation by the primary author, Frank Mahady, and the late Dr. Benjamin H. Stevens at the plenary session of the 44th Annual North American Meetings of the Regional Science Association International, November 1997, in Buffalo, New York. Unfortunately, much of Stevens's contribution was lost following his untimely death within a month of that Buffalo conference. With Mahady's encouragement, the second author, Michael L. Lahr, picked up the banner for the Mahady-Stevens concept. This paper is the first documented piece that reveals some of the concepts on the effects of reduced travel times on production and market-driven issues first discussed in that 1997 presentation.

The authors acknowledge the seminal contribution of Ian Miller, Senior Economist at Ecology & Environment, Inc. for his instrumental work in developing the freight movement data set.

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TABLE 2 Economic Effects on the Buffalo Regional Economy of a 30-Minute Average Travel Time Improvement for Freight across the Peace Bridge

	Baseline Time (No Delay)	Average Crossing Time	95th Percentile Time
To Canada	9.0	21.7	38.0
To US	8.3	21.5	83.4

Source: Battelle Memorial Institute (2002, Table 22)

TABLE 1: Peace Bridge Crossing Times in Minutes

Sector	Baseline Output ('000\$)	Effect on Output('000\$)	<i>Coefficient of Change</i>	Baseline Jobs	Effect on Jobs	<i>Coefficient of Change</i>
PRIVATE						
1. Agriculture	\$ 12,946.4	\$ 66.9	0.005	92	1	0.009
2. Agri. Serv., For., Fish	\$ 17,151.0	\$ 107.6	0.006	70	1	0.008
3. Mining	\$ 5,013.9	\$ 178.1	0.036	19	1	0.060
4. Construction	\$ 122,786.8	\$ 1,373.4	0.011	763	5	0.007
5. Manufacturing	\$ 7,447,309.7	\$ 90,676.5	0.012	36,557	450	0.012
6. Transport. & Pub. Utils.	\$ 376,592.8	\$ 5,824.6	0.015	2,501	34	0.014
7. Wholesale	\$ 384,099.8	\$ 1,940.1	0.005	3,961	21	0.005
8. Retail Trade	\$ 318,988.2	\$ 4,173.7	0.013	7,456	107	0.014
9. Finance, Ins., & RE	\$ 357,323.0	\$ 6,674.7	0.019	3,761	69	0.018
10. Services	\$ 480,462.6	\$ 7,098.8	0.015	7,459	123	0.017
Private Subtotal	\$ 9,522,674.1	\$ 118,114.3	0.012	62,638	813	0.013
PUBLIC						
11. Government	\$ 40,098.1	\$ 551.8	0.014	276	4	0.014
Total Effects (Private and Public)	\$ 9,562,772.2	\$ 118,666.1	0.012	62,914	817	0.013

TABLE 2 Economic Effects on the Buffalo Regional Economy of a 30-Minute Average Travel Time Improvement for Freight across the Peace Bridge