

Measuring Economic Benefits of Intermodal Transportation¹

By

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Abstract

Usually benefits for transportation investments are analysed within a framework of cost-benefit analysis or its related techniques such as financial analysis, cost-effectiveness analysis, life-cycle costing, economic impact analysis, and others. While these tools are valid techniques in general, their application to intermodal transportation would underestimate the overall economic impact by missing important aspects of productivity enhancement.

Intermodal transportation is an example of the so-called general purpose technologies (GPTs) that are characterized by statistically significant spillover effects. Diffusion, secondary innovations, and increased demand for specific human capital are basic features of GPTs. Eventually these features affect major macroeconomic variables, especially productivity. Recent economic literature claims that in order to study GPTs, micro and macro evidence should be combined to establish a better understanding of the connecting mechanisms from the micro level to the overall performance of an economy or the macro level.

This study analyses these issues with respect to intermodal transportation. The goal is to understand the basic micro and macro mechanisms behind intermodal transportation in order to further develop a rigorous framework for evaluation of benefits from intermodal transportation. In doing so, lessons from computer simulation of the basic features of intermodal transportation are discussed and conclusions are made regarding an agenda for work in the field.

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Introduction

Intermodal transportation can be thought of as a process for transporting freight and passengers by means of a system of interconnected networks, involving various combinations of modes of transportation, in which all of the components are seamlessly linked and efficiently combined.

Intermodal transportation is rapidly gaining acceptance as an integral component of the systems approach of conducting business in an increasingly competitive and interdependent global economy. For example, the United States Code with respect to transportation states:

It is the policy of the United States Government to develop a National Intermodal Transportation System that is economically efficient and environmentally sound, provides the foundation for the United States to compete in the global economy and will move individuals and property in an energy efficient way. The National Intermodal Transportation System shall consist of all forms of transportation in a unified, interconnected manner, including the transportation systems of the future, to reduce energy consumption and air pollution while promoting economic development and supporting the United States' pre-eminent position in international commerce. @ (49 USC, Ch. 55, Sec. 5501, 1998)

David Collenette (1997), the Transport Minister of Canada, noted: *With population growth came development, and the relative advantages and disadvantages of the different modes changed as the transportation system became more advanced.... Intermodalism today is about safe, efficient transportation by the most appropriate combination of modes. @ (The Summit on North American Intermodal Transportation, 1997)*

These statements define intermodal transportation as a macroeconomic concept, because an effective transportation system is a vital factor in assuring the efficiency of an economic system as a whole. Moreover, intermodal transportation is an important socio-economic phenomenon which

implies that the benefits of intermodal transportation have to be evaluated at the macroeconomic level, or at least at the regional level, involving all elements of the economic system that gain from having a more efficient transportation network in place.

Defining Economic Benefits of Intermodal Transportation

Traditionally, the benefits of a transportation investment have been primarily evaluated through reduced travel time and reduced vehicle maintenance and operation costs. However, according to Weisbrod and Treyz (1998), such methods underestimate the total benefits of transportation investment by *Amising other important aspects of productivity enhancement.* It is so because transportation does not have an intrinsic purpose in itself and is rather intended to enable other economic activities such as production, consumption, leisure, and dissemination of knowledge to take place. Hence, in order to measure total economic benefits of investing in intermodal transportation, it is necessary to understand their basic relationships with different economic activities.

Eventually, improvements in transportation reduce transportation costs. The immediate benefit of the reduction is the fall in total cost of production in an economic system under study which results in growth of the system's output. This conclusion has been known in economic development literature since Tinbergen's paper in 1957 (Tinbergen, 1957). However, the literature does not explicitly identify why transportation costs will fall. This issue is addressed in this discussion with respect to intermodal transportation.

Transportation is a multiple service to multiple users. It is produced in transportation networks that provide infrastructure for economic activities. It appears that transportation networks have economies of scale. As discussed below, intermodal transportation magnifies these scale effects

resulting in increasing returns to scale (IRS) of a specific nature. It implies that there are positive externalities that arise because of the scale effects, externalities that can initiate cumulative economic growth at the regional level as well as at the national level (see, for example, Brathen and Hervick, 1997, and Hussain and Westin, 1997). The phenomenon is known as a spill-over effect. Previously the effect has been evaluated through the contribution of transportation infrastructure investment to economic growth. Since Auschauer's (1989) paper many economists have found evidence of such a contribution (see, for example, Bonaglia and Ferrara, 2000 and Khanam, 1996).

Intermodal transportation as it was defined at the very beginning is more than mere improvements in transportation infrastructure. From a theoretical standpoint, it possesses some characteristics of the general-purpose technologies (GPT), and it seems appropriate to regard it as an example of the GPT, which is discussed below. It appears reasonable to study intermodal transportation as a two-way improvement of an economic system's productivity. On the one hand, it improves current operational functions of the system. On the other hand, it expands those functions. Both improvements are achieved by consolidating different transportation systems into a seamless transportation network that utilizes the comparative advantages of different transportation modes.

Improvements due to intermodal transportation are associated with the increased productivity of transportation services and a reduction in logistic costs. The former results in an increased volume of transportation per unit cost, while the latter directly reduces costs of commodity production.

Expansion of the intermodal transportation network is associated with economies of scale and better accessibility to input and output markets. The overall impact of intermodal transportation can be divided into four elements:

- (i) an increase in the volume of transportation in an existing transportation network;
- (ii) a reduction in logistic costs of current operations;
- (iii) the economies of scale associated with transportation network expansion;
- (iv) better accessibility to input and output markets.

These four elements are discussed below in a sequence.

Increase in volume of transportation in the existing network

An increase in volume of transportation can lead to economies of density - a specific scale effect. The economies of density exist if an increase in the volume of transportation in the network does not require a proportional increase in all inputs of the network. Usually the phenomenon is associated with an increase in the frequency of transportation (traffic) within the existing network (see Boyer, 1998 for a formal definition, Ciccone and Hall, 1996 for general discussion of economies of density, and Fujii, Im and Mak, 1992 for examples of economies of density in transportation).

In the case of intermodal transportation, economies of density are achieved through cargo containerization, cargo consolidation and computer-guiding systems at intermodal facilities. Cargo containerization and consolidation result in an increased load factor of transportation vehicles and higher capacity utilization of the transportation fixed facilities, while utilization of computer-guiding systems results in higher labour productivity.

For instance, in 1994 Burlington Northern Santa Fe Railway (BNSF) introduced the Alliance Intermodal Facility at Fort Worth, Texas, into its operations between Chicago and Los Angeles. According to OmniTRAX specialists, who operates the facility, BNSF has nearly doubled its volume of throughput at the intermodal facility since 1994. First, containerization of commodities being transported plus hubbing or cargo consolidation at the intermodal facility resulted in longer

trains with higher frequency. Second, all day-to-day operations at the intermodal facility are governed by the Optimization Alternatives Strategic Intermodal Scheduler (OASIS) computer system, which allowed BNSF to handle more operations with less labour.

Reduction in Logistic Costs

Intermodal transportation is characterized by optimal frequency of service and modal choice and increased reliability. Combined, these two features define the just-in-time delivery -- a major service produced by intermodal transportation. Furthermore, Blackburn (1991) argues that just-in-time delivery has become increasingly important factor in doing business globally.

It appears that just-in-time delivery reduces the burden of inventory holding costs. According to McCann (1993), total logistic costs include inventory holding costs. These costs account for a large share of the total production costs of businesses. Hence, reduction in the inventory holding costs directly improves the productivity of an economic system. The improved productivity comes from the notion that the same level of the economic system's output can be now produced at a lower cost.

Transportation network expansion and economies of size

Transportation services are produced within transportation networks. In addition to traffic, a transportation network can be characterized by the total mileage between all service points in the network. Expansion of the network implies adding new service points or/and new services. Since intermodal transportation is a system of interconnected networks, it primarily increases size of the existing network by adding new service points. Expansion of the network in this way can lead to economies of size which are a transportation analog of economies of scale in standard production theory.

Empirical research in support of existence of economies of size in the transportation networks goes back to 1960s (see, for example, Healy, 1961). The empirical evidence shows that in general, freight transportation costs are increasing at a constant or increasing rate with increase in tonnage per trip, but are increasing at a decreasing rate with increase in mileage. Since expansion of the network due to intermodal transportation is associated with an increase in the overall mileage, it eventually leads to a decreasing average total cost of transportation by pushing the volume of transportation toward an efficient scale. This phenomenon arises because of initial excess capacity of transportation vehicles and fixed facilities which is due to technical requirements.

Better accessibility to input and output markets

Expansion of a transportation network, as a result of intermodal transportation, brings in better accessibility to input and output markets. Brathen (1999) calls this backward and forward linkages to markets for supplies, inputs and final goods. Weisbrod and Treyz (1998) note that: *A highway projects have an important spatial location characteristic... They can serve to expand the market reach of businesses, allowing businesses an opportunity to realize economies of scale by serving broader markets more economically. In addition, highway system improvements can provide businesses with access to a greater variety of specialized labour skills and specialized input products, helping them to become more productive.* @

This statement defines three effects of intermodal transportation: (a) decreased production costs due to economies of scale (*to serve markets more economically*); (b) better accessibility to output markets (*to serve broader markets*); and (c) better accessibility to input markets (*access to a greater variety of specialized labour skills and specialized input products*).

Since the economies of size have already been discussed, we will focus on better accessibility to

input and output markets. Weisbrod and Treyz (1998) present an interesting framework for evaluating the productivity gain from better accessibility to input markets based on the elasticity of substitution between different inputs. In doing so, the crucial element is estimation of a production function in the form of constant elasticity of substitution (CES) with different inputs such as capital, labour, transportation, and natural resources. Econometric estimation of the CES function, a well-explored area in microeconomics, therefore provides a direct assessment of accessibility to input markets through higher substitutability of inputs.

Economic benefits from better accessibility to output markets can be defined as follows: businesses accumulate inventories over time which is defined as a stock of unsold goods. Since sale opportunities improve as a result of expanding the transportation network, via intermodal transportation businesses can sell their inventories earlier which increases their sales revenue. Hence, extra revenue from the sale of inventories is a legitimate economic benefit associated with intermodal transportation.

Setting a Framework for Empirical Analysis

In recent years new literature on economic growth has developed concerning the general purpose technologies (GPTs) (see, for example, Helpman, 1998). The term GPT is related to revolutionary technologies with significant macroeconomic spillover effects. The adjective *revolutionary* implies a technological breakthrough that is not just a simple continuous improvement, but rather a one-time large positive technological development with persistent consequences. It is said that as a GPT gradually diffuses, it affects the development of the entire economy (Barro and Sala-I-Martin, 1997). Enhanced productivity which increases the economy's long-run output, and demand for specific human capital in terms of higher skills are among the distinguishing features of the GPT.

Intermodal transportation is a good example of a GPT since it results in higher productivity and it requires special skills. With regard to the latter, new educational programs dedicated to training of specialists in intermodal transportation have appeared. For example, the U.S. Department of Transportation (USDOT) established the University Transportation Centers Program in 1981. Ten years later, USDOT added four Centers with respect to intermodal transportation under the Intermodal Surface Transportation Efficiency Act. The Denver Intermodal Transportation Institute recognized the increasing need for these specialists and hence introduced a Master's Program in intermodal transportation in September 1999.

So far, different aspects of intermodal transportation have been discussed in isolation. However, it was stated by Koulovatianos (1999) regarding GPT that a better explanation of connecting mechanics at the micro level with the overall impact on an economy is required. Applied to intermodal transportation it implies that microeconomic aspects discussed previously should be combined with macroeconomic analysis to study its contribution to economic growth. Such a framework can produce a global measure of benefits from intermodal transportation. There are three classes of models that might help us to accomplish this goal.

Computable general equilibrium models derive transportation flows from internal and foreign trade flows. For instance, a multi-regional version of this model can include the costs of delivering goods and services from producers to consumers. A change in these costs affects both the location and the levels of production and consumption, generating long term consequences for the entire economy (see Roson and Vianelli, 1993 for example of such a model for Italy).

Spatial input-output models derive transportation flows from the detailed spatial characteristics of existing transportation networks. Transportation network is regarded as a set of service points

(nodes) and the links between them. In turn, a node is characterised by a set of socio-economic characteristics. Compared to the computable general equilibrium models, the distinguishing features of spatial input-output models are explicit transportation sector as a transportation network and dynamic changes in transportation flows. Examples are in Rohr and Williams (1994), and Williams and Lindberg (1989).

Macroeconomic models with transportation incorporate transportation flows as given through the existing level of national transportation investment, the level of congestion, traffic speed, cost of the use of transportation facilities, and others. The models are expressed in a form of relationships between macroeconomic variables, usually involving time lags, which are established by statistical analysis of empirical data. Examples are Minford, Stoney, Riley and Webb (1994) and CEBR (1994).

At the present it seems appropriate to design computable general equilibrium models with an explicit transportation sector in order to study the benefits associated with intermodal transportation. Spatial input-output models are very time-consuming because they require a large amount of spatial data. In Northern America spatial input-output models can only be applied at regional levels. Macroeconomic models with transportation cannot be applied to intermodal transportation because transportation in this class of models is represented by a set of exogenous variables.

At this stage, it is possible to formulate some basic principles underlying the design of the computable general equilibrium model with explicit transportation sector:

1. A macroeconomic system is a multilevel structure with complex production and consumption patterns; as such, it is subject to a multilevel analysis in which transportation appears as a microeconomic element.

2. Transportation is an input in the general production process, because manufactured commodities are not only produced using capital and labour, but are also delivered to the consumer.
3. Transportation is a part of household consumption.
4. Transportation services are produced within transportation networks.
5. The production of transportation services in transportation networks requires capital (infrastructure and vehicles) and labour (operators of transportation vehicles).

Computer Simulation as a Demonstration Exercise

To demonstrate some theoretical finding of the above discussion, a set of computer simulation exercises were performed. As already stated, intermodal transportation results in an increase in the volume of transportation and a decrease in unit cost of transportation. The effect was simulated at the microeconomic and macroeconomic levels.

Microeconomic simulation

In an microeconomic sense, an increase in the volume of freight transportation due to intermodalism results in a one-time increase in the production of an aggregate manufactured commodity being transported. According to Batten and Karlsson (1996) the potential output for the manufactured industry in a region can be presented by the following production function:

where A is the factor productivity, T_r is a vector of variables characterising transportation network in region r , K_r and L_r represent the capital and labour in the region. Obviously, since the factor productivity is a function of transportation, an increase in the volume of transportation will result in a shift of the aggregate production function. Brathen and Hervik (1997) argue that the shift effect

proves to be significant when new fixed links replace old scheduled services in a transportation network, thus allowing for 24-hour operations and just-in-time deliveries which is the case with intermodal transportation.

The consequences of the increased transportation due to intermodalism were traced in the short and long run. For the short run simulation the following assumptions were applied:

1. A fixed transportation network: one production area and one consumption area for the aggregate manufactured good.
2. One transportation carrier serves the producer of the manufactured good only, and therefore, partial equilibrium analysis is assumed.
3. The initial volume of transportation is given exogenously.
4. The manufactured good production function captures the idea that productivity increases with increases in volume of freight transportation at decreasing rate -- an important feature of intermodal transportation.
5. Price of the aggregate manufactured good adjusts according to a linear downward-sloping demand curve which captures the assumption of monopolistic competition².
6. Amount of manufacturing capital is fixed.
7. Price of transportation or the freight rate adjusts according to a linear downward-sloping demand

² For instance, Paul Krugman (1997) emphasises that imperfect competition is a vehicle for economic growth, and transportation costs are important for generating such a growth.

for transportation.

8. Total costs of production of the aggregate manufactured good include transportation costs

9. The producer of the aggregate manufactured good maximizes profit.

When optimal value of manufacturing labour was chosen, values of the following economic variables were calculated: (i) total output of the aggregate manufactured good; (ii) price of the good; (iii) total sales revenue; (iv) total production costs; (v) profit ; (vi) overall productivity³. Volume of transportation was then increased , and the optimization problem was repeated. Then the entire exercise was repeated for the long run simulation with variable manufacturing capital and labour.

Macroeconomic simulation

The production function of the transportation network was introduced as

where K_t^F is the transportation fixed capital (transportation facilities), K_t^V is capital cost of vehicles, L_t^T is transportation labour, t is time. The production function represents the transportation network.

³ Overall productivity was defined as the ratio of output per unit of factor cost.

Then the system of five equations underlying the economy's dynamics was derived on the basis of the general equilibrium framework⁴. Combined with basic macroeconomic relationships, the production function of the transportation network allowed us to trace the consequences of intermodal transportation for the economy as a whole. A literature search, as well as an analysis of the Canadian Database, suggested specific parameter values for the model.

The derived model was calibrated with respect to the so-called *cake eating case* that describes an economy in a stationary state with the following basic property: what is produced in the economy is then re-invested to make up for capital depreciation; the rest is consumed. This implies zero economic growth. Then, fundamental macroeconomic properties of intermodal transportation -- increase in frequency of transportation and expansion of the transportation network -- were imposed on the calibrated model in a form of a one-time, ten percent increase in traffic, transportation network's capital, labour and size. The consequences of the increase were traced over time to analyze their dynamic properties.

Major findings

The microeconomic simulation exercise showed that an increase in the volume of transportation within the existing transportation network has an impact on the overall productivity in both the short-run and long-run. More specifically, a 50 percent increase in the volume of transportation resulted in a 21 percent increase in productivity in the short-run, and 26.3 percent increase in the long-run. It is also worth mentioning that eventually all microeconomic indicators, such as total production of the aggregate manufactured good, total sales revenue, total costs and profit improved in both runs. More

⁴ The derivation of the economy's general equilibrium model is not presented here because it would be too space consuming.

efficient transportation allowed the producer of the aggregate manufactured good to increase output and reduce labour input in the short-run, and slightly expand operations in the long-run.

In terms of welfare economics, total surplus increased as well. It increased by 1.3 percent in the short-run and by 1.5 percent in the long-run. The increase includes a 3.1 percent increase in consumer surplus in the short-run and a 3.6 percent increase in the long-run as well as a 0.4 percent increase in producer surplus in the short-run and a 0.52 percent increase in the long-run. This means that eventually consumers benefit more than producers from having an effective intermodal transportation in place.

These results show that benefits from intermodal transportation can be measured through improvements in the overall productivity of an economic system. However, the above discussed simulation captures only a fraction of total benefits, the fraction that is associated with improvement of current operations in a partial equilibrium framework.

The macroeconomic simulation showed that a one-time 10 percent increase in all basic characteristics of the transportation network due to intermodal transportation resulted in a permanent increase of the economy's growth rate. The growth rate was steadily increasing over the first 15 periods, reaching its maximum at value of 3.0 percent, then it decreased with passage of time and settled down at 0.4 percent. This is a long-run contribution of intermodal transportation to economic growth.

In order to give a sense of the size of these benefits, they were calculated for the first 50 periods (years). The value of the Canadian GDP of \$718 billion in 1998 was used for this purpose. It was found that total cumulative benefits from a simultaneous 10 percent increase in frequency of transportation and the transportation network expansion, as a result of intermodal transportation,

generated \$682 billion over 50 years (approximately \$13.64 billion per year). The impact of intermodal transportation appeared to be permanent and, therefore, the value presented above is an underestimation of the total economic benefits.

Concluding remarks

First of all, the results of the computer simulation are in accord with other studies:

(a) The simulation supports the conclusion of Scottish experts (SACTRA, 2000) that, in general, the contribution of transportation to economic growth, while modest, is not economically insignificant.

The obtained results also support Brathen (1999) and Hussain and Westin (1997) argument that innovations in transportation under increasing returns to scale can initiate cumulative economic growth.

(b) A frequently cited statement in the literature that total benefits from transportation should be measured through productivity enhancement of an economic system is confirmed by statistically significant values of consequences of intermodal transportation. In addition, the results of the computer simulation support Roson=s (1995) thesis about higher efficiency of a system=s optimum versus user=s optimum in transportation networks.

(c) To some extent, the computer simulation supports conclusions by Kruger (1997), Hussain and Westin (1997) and Scottish experts (SACTRA, 2000) that if economic markets are not perfectly competitive, then conventional benefit-cost analysis underestimates total benefits from transportation improvements.

Second, the computable general equilibrium approach seems to be appropriate for North America at the present. However, the proposed approach should eventually evolve into spatial input-output models with comprehensive transportation database.

Third, our macroeconomic simulation supports the proposition that intermodal transportation is an example of GPT. The macroeconomic simulation showed that the impacts from intermodal transportation were permanent which is a basic feature of the GPT.

For future work in the field, complementarity of transportation to capital and labour as inputs in the overall production process and technological indivisibilities of transportation capital have to be explicitly incorporated into the general equilibrium model. Preliminary analysis shows that these features can only magnify the resulting total benefits. As well, human capital has to be included as an important factor of production.

It is also worthwhile mentioning that some benefits from intermodal transportation, for example, savings of leisure time, improvements in road safety and positive environmental effects, are not directly related to conventional measures of economic growth. However, they have to be incorporated in future models. As an example, leisure can be explicitly included in consumers' utility functions.

With regard to simulation, future computer models should include a set of relationships and constraints based on engineering specifications of intermodal systems combined with economic characteristics of the systems. The latter should be used for specification of objective functions given engineering relationships as constraints. Coupled with an intermodal database, the models could provide a deeper understanding of the gains from intermodal transportation at different levels - single independent projects, regional and national economies. These considerations define the agenda for future economic research in the area of intermodal transportation.

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