Free Trade and Transportation Infrastructure in Brazil: Towards an Integrated Approach

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Abstract

In the development of models analyzing the impacts of free trade agreements between countries or regions within countries, relatively little attention has been paid to potential limitations imposed by transportation infrastructure. In free trade blocks such as those represented by the European Union or the USA and Canada part of NAFTA, the implicit assumption of little or no impact imposed by transportation infrastructure may be justified. However, in the case of MERCOSUL in South America, this assumption may need to be challenged. In this paper, an illustration of a potential approach to this problem will be illustrated with reference to Brazil. Attention will be devoted to the way in which the potential gains from free trade within MERCOSUL were mapped onto a highway transportation network to identify the creation of additional bottlenecks and point out the need of highway improvements once the impacts of economic development result in higher transportation costs due to such bottlenecks.

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Introduction

In modeling the welfare gains associated with the development of free trade agreements, little attention has been paid to the mechanism by which the projected increased flows of goods and services will be moved between the countries. For the most part, the models have implicitly assumed an acceptable transportation infrastructure with enough capacity to absorb increased demand on the highway systems. However, in developing economies, these assumptions are less tenable; in the euphoria surrounding the creation of MERCOSUL/MERCOSUL, the free trade agreement between Brazil, Argentina, Paraguay and Uruguay, the promise of enhanced trade was not measured against some fundamental realities. For example, it was noted that three-quarters of all terrestrial trade between Brazil and Argentina (with some additional trade with Chile) uses a single bridge across the Uruguay River (Economist, 1996). In fact there are only two other bridges linking these two countries; obviously, increased trade will face significant transportation and transfer costs, and these have not been prominent features of most general equilibrium models that have explored MERCOSUL to date.

This chapter offers a modest first step in an attempt to place the gains from trade onto a highway transportation network in the hope that some of the major sources of capacity limitations and bottlenecks can be identified. The Brazilian transport configuration is currently characterized by highly concentrated flows of products and services on its highway system, whereas the railroad and inland waterway modes are not considered to be of primary importance. Notwithstanding this concentration, where more than 60% of the general freight is carried by heavy highway vehicles, there have been few efforts directed to continuous and endurable planning for maintenance, operation, safety, and even modest expansion of the highway network, especially within the last two decades. The other modes, such as railways, inland waterways, and coastal navigation, have offered non-competitive levels of productivity and efficiency. For example, inland waterways account for just 1% of the general freight, notwithstanding the fact that the country has approximately 20,000 miles of navigable rivers. The railroad system, once considered a critical element in the process of territorial integration, has faced a tremendous deterioration in its equipment and operational network and in the morale of the personnel, so that the Brazilian rail transportation has come perilously close to financial disaster; recent privatization efforts (many involving international investors) may offer some hope for a rebound in its fortunes.

In this chapter, a set of simulation exercises was conducted to examine the likely consequences of the trade agreements, especially MERCOSUL, on the efficiency, capacity, and development of the highway system in Brazil. The main reason to consider MERCOSUL as the main source of trade impacts and changes in the traffic volumes is exactly because this trade agreement is the major factor to the increase of demands for better and more competitive transportation facilities in Brazil. Accordingly, capacity problems, which cannot be solved in the short run, are evaluated in terms of their potential costs to the economy - i.e., lost output or increased highway transportation costs that reduce the competitiveness of the sectors. In this case, it is assumed that highway bottlenecks result in higher costs when compared to efficient and productive transportation links. One of the major contributions of this analysis is the identification of the specific role highway transportation plays in the economy, based on which some suggestions for priorities in investments are presented, for the existing facilities should be upgraded in terms of capacity levels. Naturally, due to space limitations, many of the details of the original study could not be presented; however, the general findings of the impacts of MERCOSUL upon the current Brazilian highway transportation system still offer some important insights.

The Overall Modeling System

A myriad of economic models have been employed to project the impacts of free trade agreements among countries, or regions within countries, but there have rarely been initiatives to measure the effects, or impacts, of such agreements upon the efficiency of highway transportation networks even to the extent of measuring efficiency as the ratios between traffic volumes and operational capacities. When a transportation system is already built and planned to accommodate the increases in demand, the impacts of the economic changes are relatively and proportionally spread out along the spatial and temporal arrangement of the traffic volumes. Such a dynamic process becomes even more perceptible when a highway transportation system exists and operates under highly efficient standards of travel time, operational costs, and safety. However, when the existing transportation infrastructure is deficient and lacks the basic elements to properly move the products along the networks, the economic impacts of any proposed increases in demand are likely to negatively affect the routes, leading to additional bottlenecks or critical segments. In most developing countries, this latter option is the one that is found more often; it arise in large part because the transportation infrastructure needs massive investment to avoid the transportation facilities becoming a barrier to the global competitiveness of the free trade member countries. Accordingly, it is necessary to evaluate and analyze the impacts of the free trade agreements on transportation facilities through a methodological approach where the links between trade and transport can be quantified and applied to the parameters that measure the efficiency of moving goods and services.

In this chapter, MERCOSUL in South America is taken as the paramount element to generating economic changes in Brazil, where its impacts in the Brazilian highway transportation infrastructure may lead to additional bottlenecks and, consequently, to opportunities to help realize the gains from international trade. To facilitate this exploration, two economic and one transportation model are combined and analyzed together, so that the economic impacts can be transposed to effects on efficiently moving goods and services within the Brazilian highway network. The first economic model is a macro econometric model providing annual forecasts for the Brazilian economy at the macro level up to the year 2014 (for a description of this model see Fonseca, 1991). The results of this model are then feed into a five-region interregional model of the Brazilian economy (see figure 1 for the location of the macro regions). The forecasts generated by the macro econometric model are used as a guide to determine how the five regions and their associated economic sectors in the interregional model would grow during the period, as well as the flows of goods among the regions. The transportation model is based on the relationship between traffic volume and operational capacity (V/C) for each highway segment. The parameter V/C can be stratified into ranges of levels of service, where each level of service is a qualifying endowment of the V/C ratio.

Any sort of mathematical approach to analyzing trade-transportation data and, by any means, to numerically linking these two concepts demands a type of theoretical background that is able to support the assumptions and lines of thoughts of the mathematical analysis itself. In this study, the theoretical foundation behind the mathematical exercises is constructed through the specification of regional parameters. Within each region, each highway segment links a production pole to a consumption pole. Accordingly, the goods and services are transported along the existing highway facilities, leading to traffic volumes that can be easily quantified. Each segment, however, has an operational capacity limited to geometric conditions, percentage of heavy vehicles in the traffic mix, terrain, driver's composition, and so on. Therefore, several adjustments need to be made in the development of the relationship between volume and capacity, and thus the determination of the level of service for each highway segment.

With the assumption that each highway segment will move the production of a certain pole in the direction of the consumption center, an expansion in consumption or production in any of these poles will lead to an increase in the traffic volume of the segment linking the two poles, thereby altering the volume-to-capacity ratio. This is exactly the principle that will direct all the analyses in this study, where MERCOSUL is the main generator of trade factors that will change the production/consumption levels of the Brazilian poles.

The paper provides a mechanism to link the trade impacts resulting from the economic model and the highway transportation parameters that identify the operational conditions of the highway facilities. From the economic model, given the implementation of MERCOSUL, a series of impact coefficients among the regions within Brazil can be generated. These coefficients must affect the highway transportation facilities in such a way that the increases in transportation demands reflect the magnitude of the economic forecasts. In other words, the changes in traffic volumes, given the free trade agreements, must mirror the economic impacts, for they are quantified by the economic coefficients. Based on the nature of the trade-transportation linkages, the main hypothesis is that within a certain period of time, MERCOSUL would generate percentage change in interregional and intraregional trade in Brazil, and that these changes, depicted by the impact coefficients, would affect the highway system, with increases in the traffic volumes, which will result in increases of the V/C ratios, thereby leading to decreases in the levels of service of the highway segments.

When the two models are aggregated and the impacts of MERCOSUL in the Brazilian highway transportation systems are evaluated, the operational efficiency of the highway segments can be investigated to answering the following questions:

- Are the goods and services being moved along the transportation network through the most efficient highway routes?
- Are there any problems of under- or over-estimation of the network capacity?
- Is the distribution of flows across the highway being used in its most efficient way, within an optimized format as far as the economic context demands, it means without creating bottlenecks?

By answering these questions, it would be possible to build a planning strategy that considers not only the current demands for a better way to transport goods and services, but also the projected effects of the free trade agreements on higher demands for a highway transportation system where competitiveness is taken as the economic target.

<<insert figure 1 here>>

The Economic Model

To obtain the results for the impact of MERCOSUL over the flow of the goods and services inside and among the Brazilian regions, an interregional model for the Brazilian economy was constructed at the level of five regions (South, Southeast, North, Northeast, and Central West, as shown in figure 1), 26 sectors and 43 categories of goods and services.

The forecasts at the macro level, to the year of 2014, are derived from an econometric model that was used as a guide to determine how the intra- and inter-regional relations would change in the

Brazilian economy. In addition, as attention is directed essentially to international transactions, forecasts were also made for the growth of exports and imports of the five regions.

As the main focus of this study is the role of trade into the highway transportation infrastructure, the results from the economic models were used to create indexes of growth of the intra- and inter-regional flows of those goods that have a more intensive use of transportation systems. For the international flows, attention was directed to all the goods.

The results are summarized in the figures 2 to 14. What one can see is that the interregional flows grew more in the Central West region, followed by the South, Southeast, North, and Northeast region. For exports, the larger growth rates are found in the Central West, followed by the North, Northeast, South and Southeast regions, while imports grew more vigorously in the North region, followed by the Central West, South, Southeast and Northeast regions. The higher growth rates of the external sector of the Central West and North regions are due to the fact that these regions have a low value of imports and exports in the base year, as compared to the other regions. In such a way, greater trade liberalization has a tendency to increase the external flow (in percentage terms) from these regions, more so than in the other regions.

When attention is directed to the interregional flows, what one finds is an increase in the relations among the North, Northeast, and Central West regions. The exports of the North region to the Central West and Southeast regions grow more than those to the South and Northeast regions. The imports from the Northeast and Central West increase considerably more than the ones from the other regions. The exports of the Northeast region increase to the Central West region while showing about the same growth to the other regions. The growth of imports from the other regions to the Northeast was at about the same level.

The exports of the Central West region grew more to the North and Southeast regions and less to the Northeast and South regions. The imports grew more from the North and Northeast regions and less from the Southeast and South regions. The exports of the Southeast region expanded more to the Central West, South, and Northeast regions than to the North region. The imports grew more from the North and Central West regions and less from the South and Northeast regions. Finally, the exports of the South region increased more to the Southeast, Central West, and Northeast regions, and less to the North region; imports from the North and Southeast regions had higher growth rates than the ones from the Northeast and Central West regions.

<<insert figures 1-13 here>>

The Trade-Transportation Links

The aggregation of the trade-transportation models was conducted through several steps, where the primary concern was the spatial, or regional, standardization of the coefficients to be applied to the highway traffic volumes. Figure 15 shows a schematic sequence of these steps. The spatial partitioning used in the economic model, as related to MERCOSUL and Brazil, was defined by macro-regions shown in figure 1. The transportation model grouped six corridors, based on the main routes of goods and services around the country. So, the transportation model can be characterized as a user-optimizing network production model taking into consideration the level of congestion in the critical points of the system. From the economic models considered there had to be a statistically significant representation of products within each economic sector in the O-D matrix.

<<insert figure 15 here>>

Accordingly, data were collected on the origin and destination of 53 products, totaling approximately 300 million tons, and encompassing 23 out of 27 states in Brazil; the remaining 4 states are located in the Amazon Region where production and consumption are not significant enough to create large highway flows. The sample size then represented 55% of the total traffic volume on the Brazilian highways in an average year of the 1990´s. Considering that the most important products would be those whose aggregate value is relatively low, but with high growth rates, the sample size showed may be claimed to be fully representative of the total origin-destination flow pattern in Brazil. Notwithstanding, several tests were conducted to evaluate the representation of the regional distribution of the products, so that a lack of equilibrium among the several production/consumption areas could be avoided.

The stepwise analysis to standardize the trade coefficients to be applied to the highway traffic volumes had the following sequence:

1. Within a certain forecasting period, there exists only one, trade coefficient from, say, macro-region A to macro-region B, from macro-region A to macro-region C, and so on;

2. Since every corridor encompassed one or more macro-regions, a simple average was calculated to represent only one trade coefficient to each corridor. It is important to emphasize that one region may be part of more than one corridor; that is why an average of the coefficient had to be considered. However, it is also important to note that, since the regional differences between the two

models were not that critical, and since the nature of trade is naturally concentrated (gravity theory), the simple averaging procedure did not lead to significant distortions;

3. The flows among the corridors were identified by an origin-destination matrix. Since the O-D matrix was made of micro-regional production/consumption poles, it was possible to aggregate those poles into macro-regional groups within the corridors. In this way, the percentage participation of each corridor-to-corridor flow as related to the total traffic volume of a certain corridor could be achieved;

4. By using these percentage participations as weights, a single weighted trade coefficient was created for each corridor, within a certain forecasting period;

5. Assuming that all the products considered in the O-D matrix were not subjected to significant transformations from the origin to the destination (i.e., low aggregate value and high growth weight), it was feasible to assume that a certain percentage change in trade could be directly and linearly applied to the highway traffic volumes. However, this linear effect would be only valid for the heavy goods' traffic; one cannot assume that the changes in trade will linearly affect the use and thus the volume of passenger cars. Since the operational capacity takes into account the heavy traffic factor as resulting from truck-passenger car's equivalent values, the heavy goods' traffic participation in the total traffic flow was taken as the major reduction factor in the trade coefficients;

6. After achieving a reduced trade coefficient for each highway segment, the V/C ratios were indexed by the trade coefficients to reflect the impacts of MERCOSUL in the highway transportation network of the six corridors.

Based on this stepwise analysis, it was possible to identify one trade coefficient for each forecasting period, from 1997 to 2014, within each corridor. The following equation shows the mathematical standardization of the trade coefficients for each corridor:

$$I_{c1i} = \left[\left(I_{11} * W_1 + I_{12} * W_2 + I_{13} * W_3 \right) / 100 \right] * R_{\% hv1}$$

where,

I_{c1i} - weighted impact coefficient for corridor 1 in the *i* period for a certain highway segment;

I_{11} - averaged coefficient resulting from the individual coefficients from regions of corridor 1 to corridor 1;

W_1 - percentage participation in total flows of corridor 1 to corridor 1;

I_{12} - averaged coefficient resulting from the individual coefficients from regions of corridor 2 to corridor 1;

W_2 - percentage participation in total flows of corridor 2 to corridor 1;

I_{13} - averaged coefficient resulting from the individual coefficients from regions of corridor 3 to corridor 1;

W_3 - percentage participation in total flows of corridor 3 to corridor 1;

$R_{\%hv1}$ - reduction coefficient based on the heavy vehicle percentage for a certain highway segment.

Given the this stepwise analysis, it was possible to apply the trade coefficients to the each V/C ratio from 1997 to 2014, thereby quantifying the deteriorations in the level of service of each highway segment. From this analysis, it was possible to identify the main bottlenecks within the Brazilian highway system.

Main Findings

Among the several analyses that have resulted from the mathematical linkage between the trade and the transportation models, one that has been of utmost importance is the trade effect that generates bottlenecks in the main highway segments, given the already deteriorated conditions of the Brazilian highway system. This study has shown that one of the main consequences of the impacts of the MERCOSUL free trade agreements on the Brazilian highway network is the increase in the number of critical points, or bottlenecks, in most of the corridors. Of course, the assumption was made that investments in transportation infrastructure that would be made over the forecast period would be allocated primarily for maintenance rather than system expansion. According to figure 16, there is an increasing pattern concerning the number of bottlenecks, generating negative consequences, mainly in those corridors where the primary routes cross largely industrialized regions, such as São Paulo, the biggest metropolitan area of South America, and in the Central-East, where the Rio de Janeiro and Belo Horizonte metropolitan areas are located. Almost all the main Brazilian industrial plants are concentrated in these two corridors, such as automobile, steel, fabricated metals, paper and cellulose, food processing and services. These three metropolitan areas account for more than 60% of the Brazilian GDP.

<<insert figure 16 here>>

Figure 16 shows, for example, that the impact of MERCOSUL on the highway system of the São Paulo corridor accounts for an increase of, approximately, 25% in the number of bottlenecks within the projection period. Moreover, in the Central-East corridor, this increase reaches 60%, going from 10 critical points to 16 in the year 2014. The same pattern can be realized for the other 4 corridors, the major difference being the existence of a smaller number of bottlenecks, but the deterioration patterns are similar to those observed in the São Paulo and Central-East corridors.

The influence of the free trade agreements in the Brazilian highway systems shows the potentially negative consequences of not being prepared to handle the increases in demands. It is important to note that the deterioration of the level of service in one highway segment has a ripple effect that spreads out the operational condition of that bottleneck to a large area along the main route. In other words, once the quality of service on a highway segment is deteriorated, the effects in the main operational parameters are multiplied along other segments of the main and adjacent routes, leading to higher transportation costs, increases in travel time, decreases in safety and, by any means, reductions in the competitiveness. In turn, this may translate into increases in the final prices of the products, potentially undermining the gains from trade. Therefore, this investigation has achieved its main objective, namely the detection of the influence of the implementation of MERCOSUL upon the main corridors of the Brazilian highway system. These negative effects are to continue not only due to MERCOSUL, but also because of the increasing globalization of the economy that also affects the internal flows of goods and services.

Conclusions

In considering the impacts of MERCOSUL, together with the globalization and stabilization of the Brazilian economy, the highway transportation systems must be analyzed through a regional perspective, where the trade characteristics of each area can be investigated and updated to the needs of a better transportation infrastructure. The spatial distribution of activity is not uniform and the consequences of international trade agreements are unlikely to yield similar benefits to all regions of the country (see Haddad and Hewings, 2001a, b). . In the Central part of country, what has been noticed is a limitation in competitiveness increase due to a transportation system with high levels of deterioration, with directly reflects on travel time, transportation costs, safety and so on. .

Based on these findings, a certain number of initiatives could be taken to improve the Brazilian transportation system. First, Brazilian transportation development has ignored, until recently, opportunities to expand development of multimodal systems, to exploit the efficient competitive contributions of each mode and to relieve the over dependence on highway transportation exclusively. Regulatory reform has proceeded, albeit slowly, to reduce bureaucratic interference in the development of efficient transportation systems and to encourage foreign direct investment. An acceleration of the privatization processes of highways and railroads would certainly offer opportunities for much needed investment, investment that is unlikely to be forthcoming from state and federal governments facing significant fiscal problems. Thirdly, there is a pressing need to enhance the participation of the railroad and inland waterway systems in the Brazilian transportation system; at present less than 1% of interstate trade using the extensive waterway system. Fourthly, there is still a significant economic basis for capacity expansion of some highway segments, where the distance between nodes makes other forms of transportation less competitive.

Given this overall outlook for the Brazilian transportation system, there must be a planning program that provides a detailed inventory of the main investment targets, of course, according to a spatial and temporal schedule of investments. If this program becomes a reality, then the transportation sector can be adjusted to enhance Brazilian competitiveness both in the internal and external markets.

Nevertheless, it is important that the past and still current mode of thought of the Brazilian decision-makers be changed to a more comprehensive analysis of the role to be played by infrastructure systems, so that the financial resources will not be applied to inefficient transportation segments.

While Brazil-specific investment needs are not known, it was estimated (Economist, 1996) that the southern South American countries would need $20 billion in infrastructure investment just to keep pace with demand growing at 4-5% per year. However, this estimate is a probably far too low since it only includes investment at the margin and assumes that the existing infrastructure is adequate; this is far from the case.

Finally, the analysis conducted here reinforces some recent remarks about international trade research:

> Most international trade research in the past has ignored the geographic dimension. International trade models, whether empirical or theoretical, whether based on small-country or large-country assumptions, and whatever else their attributes, tended until recently to have one curious thing in common: they treated countries as disembodied entities that lacked a physical location in geographic space. ... many of the more interesting aspects of regional trading arrangements require the introduction of a geographic dimension (Frenkel, 1996)

While it may not be possible to invest in the effort needed to link transportation systems with computable general equilibrium (CGE) models, greater attention will need to be placed in the typically nested production functions and consumer choice functions to reflect variations in transportation and transfer costs in addition to variations in production and tariff costs. The results presented by Kim (1998), Kim and Kim (2002) and Kim *et al*. (2002) point to the significant insights that can be gained from integration of transportation and CGE models. Without such an effort, the results from separate, unlinked models may not accurately reflect the gains to trade and some of the major source of non-tariff impediments to the realization of those gains.

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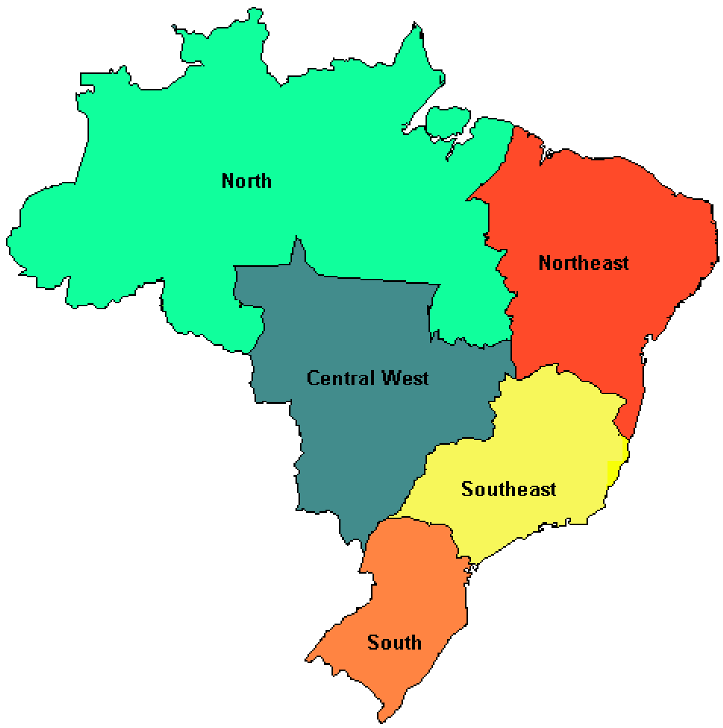

Figure 1. Macro Regions of Brazil

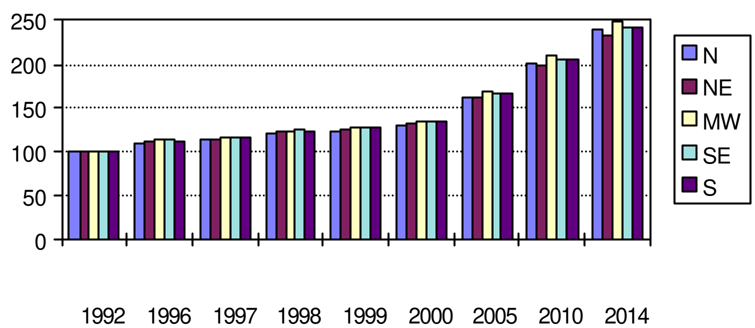

Figure 2. Index of Growth of the Transport Demanding Goods [1992 = 100]

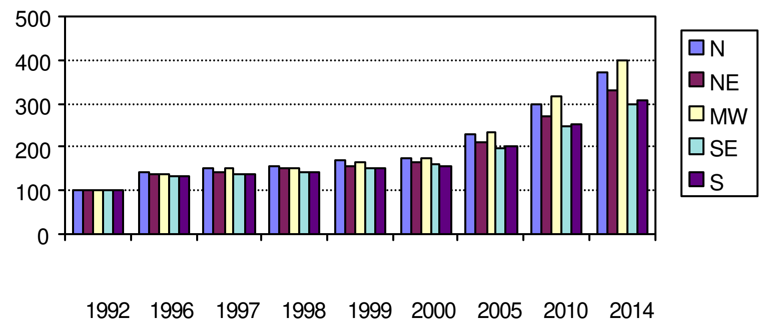

Figure 3. Index of Growth of Exports to the External Market, by Region [1992 = 100]

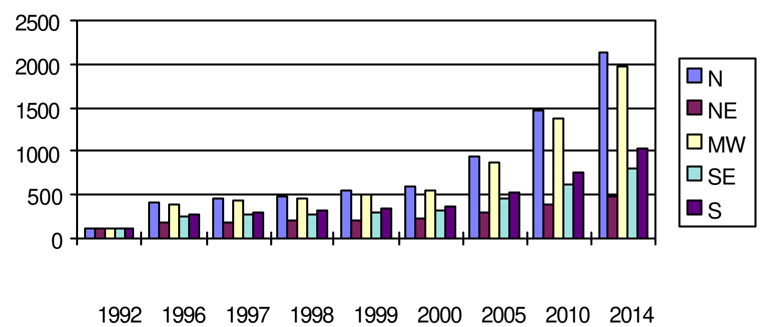

Figure 4. Index of Growth of Imports from the External Market, by Region [1992 = 100]

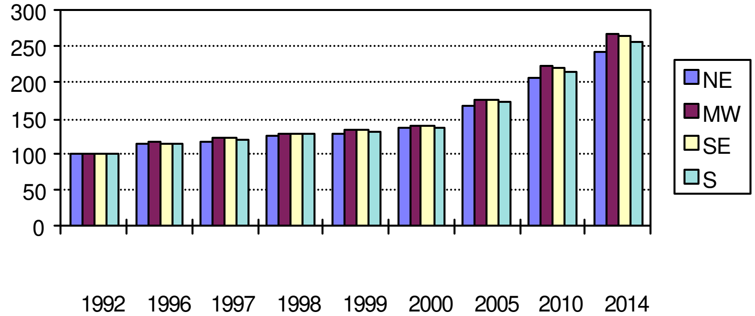

Figure 5. Index of Growth of Regional Exports - North Region Transport Demanding Goods [1992 = 100]

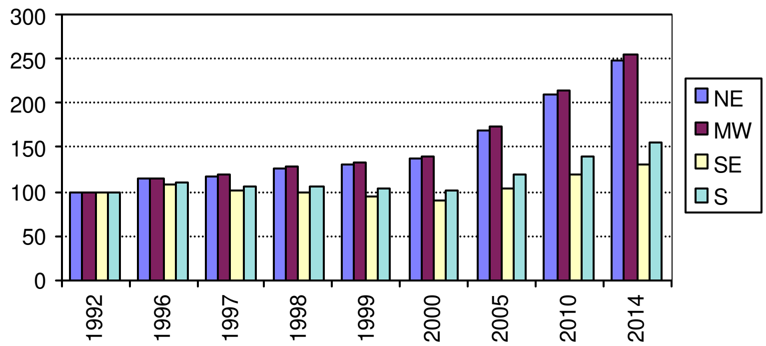

Figure 6. Index of Growth of Regional Imports - North Region Transport Demanding Goods [1992 = 100]

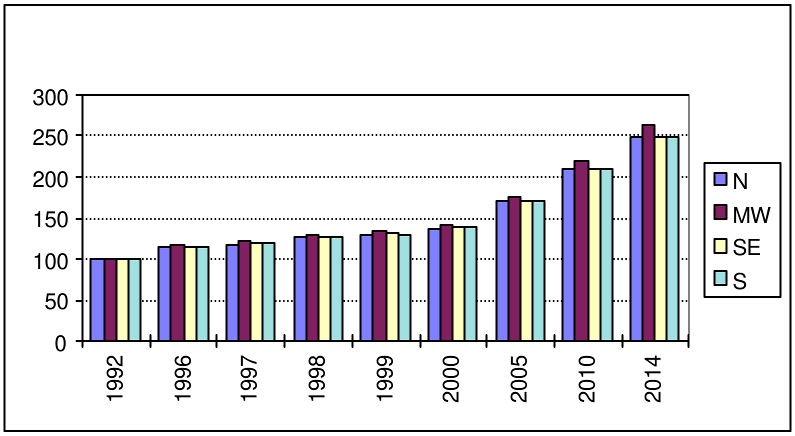

Figure 7. Index of Growth of Regional Exports - Northeast Region Transport Demanding Goods [1992 = 100]

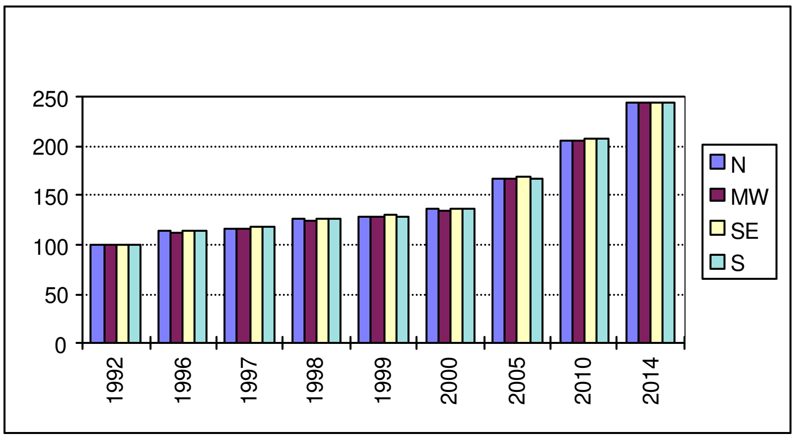

Figure 8. Index of Growth of Regional Imports - Northeast Region Transport Demanding Goods [1992 = 100]

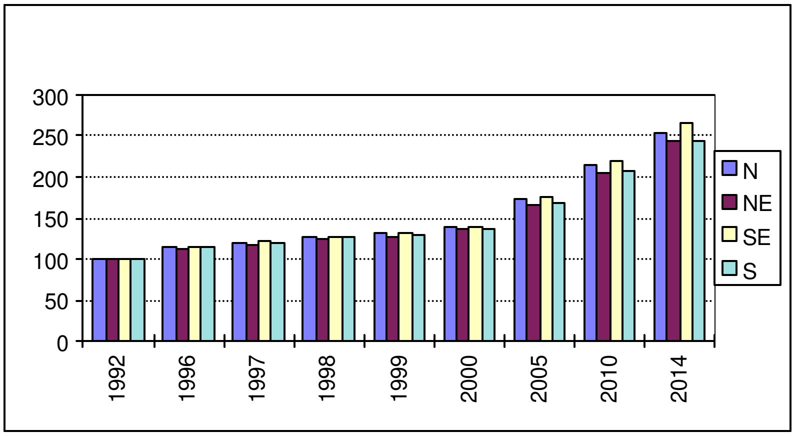

Figure 9. Index of Growth of Regional Exports - Central West Region Transport Demanding Goods [1992 = 100]

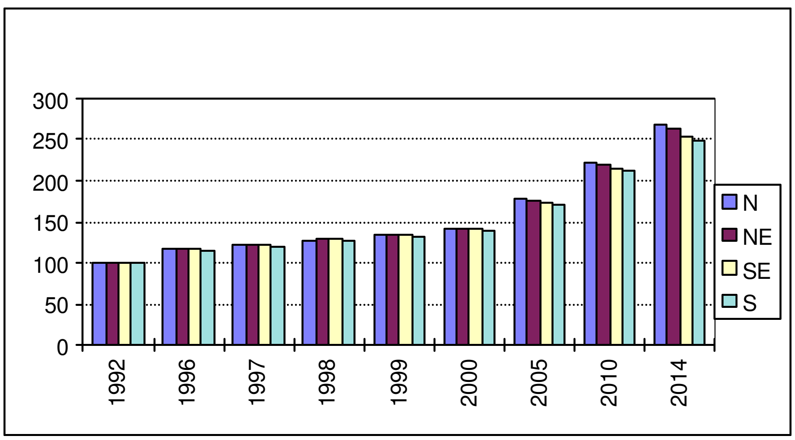

Figure 10. Index of Growth of Regional Imports - Central West Region Transport Demanding Goods [1992 = 100]

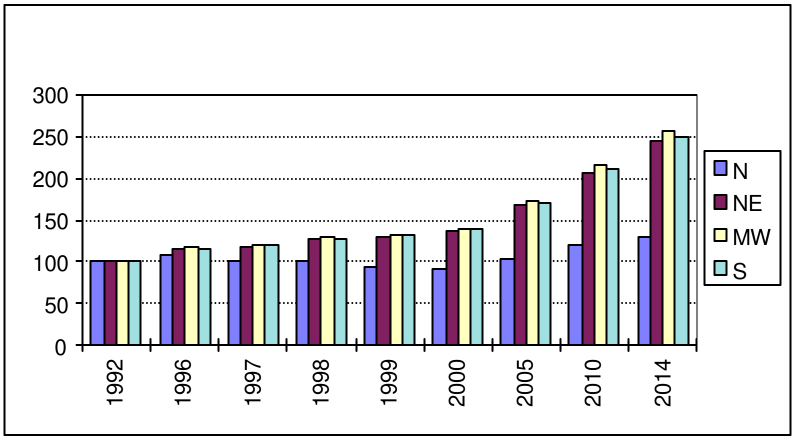

Figure 11. Index of Growth of Regional Exports -Southeast Region Transport Demanding Goods [1992 = 100]

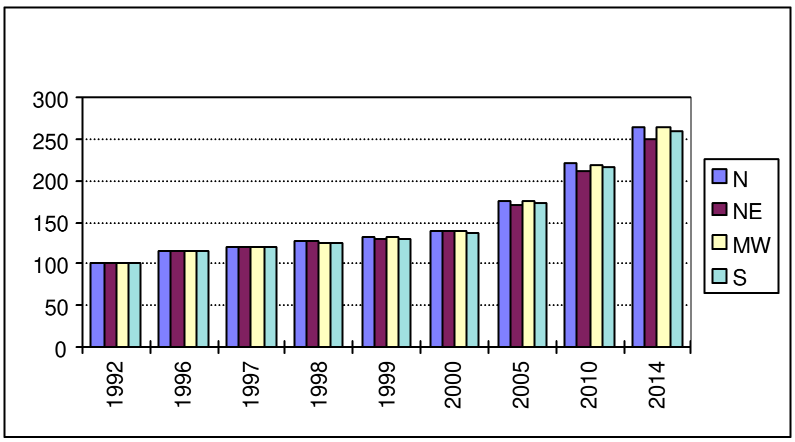

Figure 12. Index of Growth of Regional Imports - Southeast Region Transport Demanding Goods [1992 = 100]

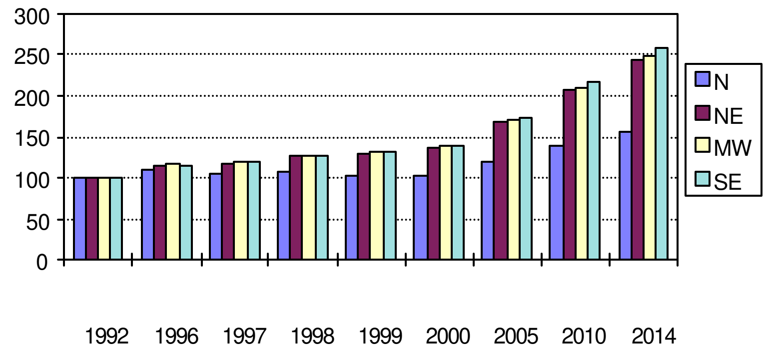

Figure 13. Index of Growth of Regional Exports - South Region Transport Demanding Goods [1992 = 100]

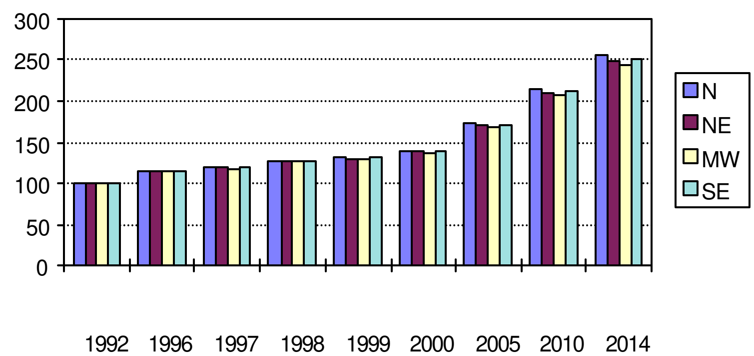

Figure 14. Index of Growth of Regional Imports - South Region Transport Demanding Goods [1992 = 100]

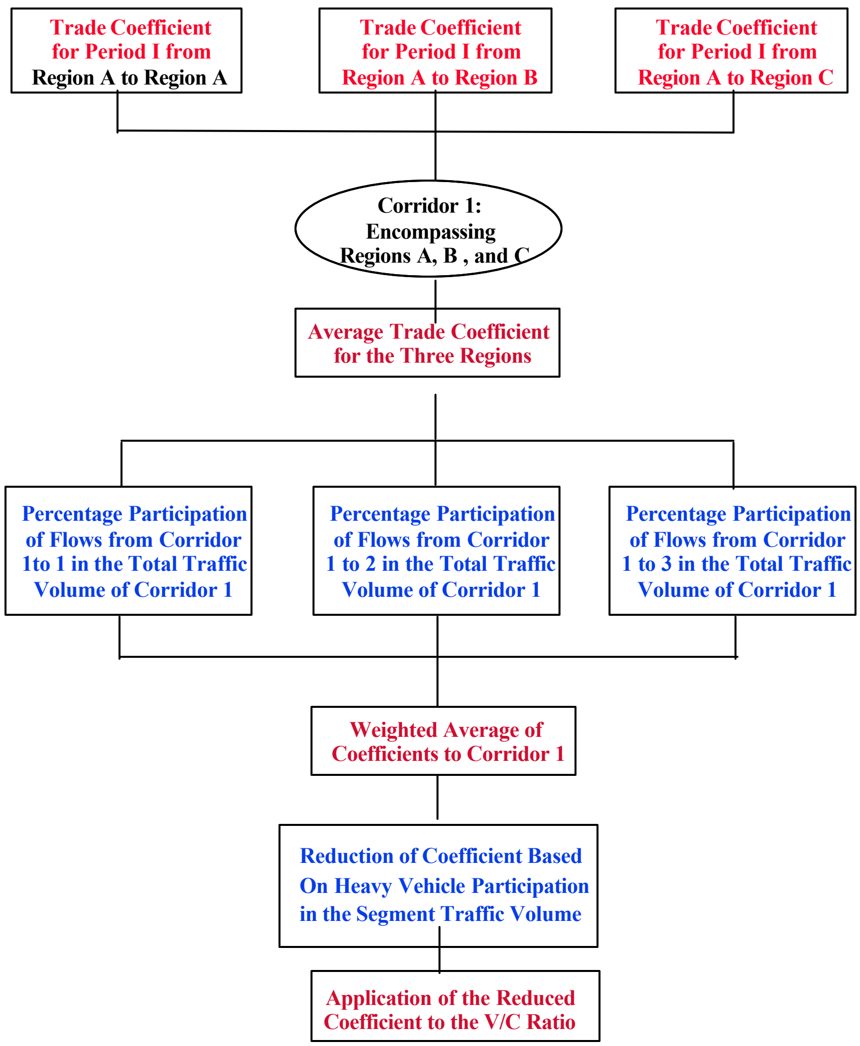

Figure 15. Stepwise Analysis of the Economic Impacts of MERCOSUL: a Three-Region, Three-Corridor Example

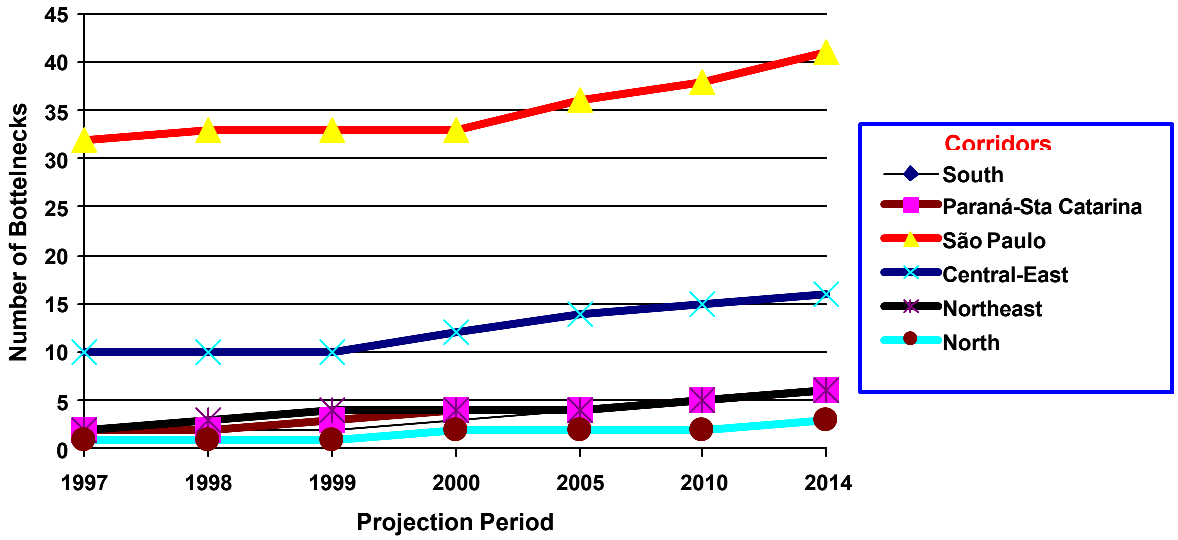

Figure 16. Number of Highway Bottlelnecks by Corridor Based on the Impacts of Trade Coefficients on Traffic Volumes