Regional Integration in Colombia: A Spatial CGE Application

Eduardo A. Haddad,* Ana M. B. Barufi,§ Silvio M. A. Costa°

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Abstract

We explore an alternative approach to bridge the gap between New Economic Geography (NEG) theory and practice. We depart from Haddad and Hewings (2005). which offers some preliminary steps in the marriage of some of the theoretical foundations of NEG with spatial computable general equilibrium (CGE) models. It is argued that such approach should not be neglected as a potential modeling strategy to be pursued in order to reinforce policy relevance of NEG-based models. We apply the proposed methodology to look at the ex ante potential spatial implications of reductions in transportation costs within the Colombian economy. The results are shown to be in line with NEG models, reproducing empirical regularities evidenced from econometric estimates.

Keywords: spatial general equilibrium, transportation cost, new economic geography.

JEL Classification: R11, R13, R15.

Integrazione regionale in Colombia: **Un'Applicazione Spaziale CGE**

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Sommario

Ouesto lavoro esplora un approccio alternativo al superamento del gap tra la teoria della Nuova Geografia Economica (NGE) e la sua verifica empirica. Il modello proposto da Haddad e Hewings (2005) rappresenta un tentativo di coniugare alcuni dei fondamenti teorici della NGE con i modelli di equilibrio generale spaziale (CGE). Questo cinaino tale metodologia al fine di analizzare, *ex ante*, le implicazioni spaziali di una riduzione dei costi di trasporto nell'economia colombiana. I risultati sono consistenti con quanto predetto dai modelli NGE e supportati da robuste stime econometriche del Parole chiave: equilibrio generale Parole chiave: equilibrio generale, costi di trasporto, nuova geografia economica.

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Department of Economics, University of São Paulo, Av. Prof. Luciano Gualberto, 908, 05508-900, São Paulo, Brazil e-mail: ehaddad@usp.br. Corresponding author.

Department of Economics, University of São Paulo, Av. Prof. Luciano Gualberto, 908, 05508-900, São Paulo, Brazil, e-mail: ana.barufi@gmail.com.

Department of Economics, University of São Paulo, Av. Prof. Luciano Gualberto, 908, Document to exclusi 05508-900, São Paulo, Brazil, e-mail: silvio@usp.br.

1. Introduction¹

Theoretical developments in the new economic geography (NEG), emphasizing the three-way interaction among increasing returns, transportation costs, and the movement of productive factors, have provided a common approach to be used in the fields of regional, urban and international economics (Fujita et al., 1999). Emphasis on pure form has proved important to help avoiding mistakes in logic and to provide a classificatory scheme to use in organizing ideas. However, NEG has not vet succeeded in passing from the realm of pure theory to that of applied theory or actual practice. Even though a recent body of research has been emphasizing its empirical relevance – both through the development of applied theory to discuss policy issues², and empirical tests for validation of the theoretical results –, little effort has been directed to apply this framework to concrete problems in economics, and to reach the planners. In a sense, NEG still faces the so-called Cournot's problem.

More than half a century has passed since Milton Friedman first drew the attention to Cournot's problem. In his review of William Jaffé's translation of Léon Walras' Elements of Pure Economics, Friedman (1955) highlighted the task Cournot (1838) had outlined in his Researches as the proper way of dealing with the interrelationships in an economic system. In this author's opinion, the development of economic analysis of concrete problems should pursue a 'general equilibrium' framework, as "in reality the economic system is a whole of which all the parts are connected and react on each other" (op. cit. p. 127). 'Partial equilibrium' analysis, even though more tractable from an analytical perspective, would not provide a complete and rigorous solution for the problems relative to some parts of the economic system, as it does not accomplish to take the whole system into consideration. However, Cournot recognized that the existing mathematical, statistical and computational benchmarks, at the time of his writings, were far from sufficient for approaching the problem in a general equilibrium context.³

The quest for solving Cournot's problem may be evoked considering five main lines of contributors: (i) the predecessors that provided the intellectual background which influenced the work by Léon Walras, including pioneering efforts of the eighteenth century economists Richard Cantillon and François Quesnay towards making the circular flow of income concrete, as well as the often neglected influence by Achylle-Nicolas Isnard (Schumpeter, 1954); (ii) the key role played by

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^{1.} The paper originates from the 7th Annual Conference of the Euro-Latin Study Network on Integration and Trade (ELSNIT) - Trade and Regional Disparities, which took place at the Kiel Institute for the World Economy (IfW). ŝ

See Baldwin et al., 2003, for a synthesis of different approaches used to address policy issues 2. with NEG models.

^{3. &}quot;It seems, therefore, as if, for a complete and rigorous solution of the problems relative to some parts of the economic system, it were indispensable to take the entire system into consideration. But this would surpass the powers of mathematical analysis and of our practical methods of calculation, even if the values of all the constants could be assigned to them numerically." (op. Document to exclusiv cit., p. 127).

Léon Walras himself, whose major "achievement was to having constructed a mathematical system displaying in considerable detail precisely the interrelationships emphasized by Cournot" (Friedman, 1955, p. 904); (iii) a line of economists, led by Kenneth J. Arrow and Gérard Debreu, whose successful accomplishments in the realm of pure theory reinforced Walras' initial strategy of emptying Cournot's problem of its empirical content and producing a complete and rigorous solution 'in principle', making no pretense that it could be used directly in numerical calculations⁴; (iv) the seminal works by Wassily Leontief, Leif Johansen, Sir Richard Stone and Herbert Scarf, in the realm of applied theory, whose contributions represent milestones in the development of the main schools of computable general equilibrium (CGE) modeling; and, finally, (v) in the realm of actual practice, the development of CGE models, which offer an adequate framework for policy analysis, by quantifying linkages between different parts of the economy and providing useful insights on the likely effects of disturbances in one part of the economy on activity in other parts (Dixon, Parmenter, 1996).

Considering Cournot's problem in the NEG context requires understanding the development of the field. It is relatively well acknowledged the intellectual background that influenced theorists of NEG (Fujita et al., 1999). It is also recognized that the NEG approach deals properly with location and agglomeration: no other body of work explains agglomeration in a theoretical framework that is tractable, has solid micro foundations, and makes testable empirical predictions (Neary, 2001). To a certain extent, it may be agreed that there are few major issues still to be resolved in the realm of pure theory. As far as empirical relevance is concerned, we see a recent increase in the number of studies trying to test theoretical predictions of NEG models, which have been further developed to produce analytical insights to the policy debate. Thus, nowadays focus is on the realm of applied theory. Nonetheless, NEG applications have not reached the ground for fulfilling the policymakers' needs for analysis of regional development policies.

In this paper we explore an alternative approach to fill this gap. We depart from Haddad and Hewings (2005) modeling approach, which offers some preliminary Inch limitations, we will argue that this approach should not be neglected as a potential modeling strategy to be pursued in order to reinforce policy relevance of NEG-based models (see Patridge, Rickman, 2008 for a review). Its ability to be used in commence of the economic system. economic system with explicit forward and backward linkages places spatial CGE models as strong candidates for bridging the gap between theory and practice.

The case study addressed in this paper is particularly interesting. We will consider reductions in transportation costs in the Colombian economy to look at its implications to spatial allocation of resources. Colombia's spatial structure is characterized

^{4.} Friedman called this strategy a solution for the problem of form, not of content: of displaying an idealized picture of the economic system, not of constructing an engine for analyzing concrete Document to exclusiv problems (Friedman, 1955, p. 904).

by strong polarization from the capital city, Bogotá, whose location may, at first, present a puzzle. Bogotá is located at the geographic center of Colombia, in a high plateau in the Andes mountains, with difficult access to the main seaports and with poor connections to other regions and countries by land (Pachón, Ramírez, 2006; Cárdenas et al. 2006). The very location of Bogotá presents a challenge to Colombian global integration as market/supply access from/to the economic core of the country is hindered by high internal transportation costs.⁵

The paper begins an exploration of the Colombian economy using a spatial computable general equilibrium model that is in the process of being unfettered from the reins of the perfectly competitive modeling paradigm. The process is ongoing and difficult; attempts to handle non constant returns to scale, agglomeration and core-periphery phenomena, imperfect competition, and transportation costs present enormous challenges and still have to rely on some modeling shortcuts. Put together, the analysis becomes even more intractable. However, these steps will be necessary if general equilibrium models are to achieve credibility in their ability to mimic changes in spatial structure and to provide policy makers with some reasonable degree of confidence in the measurement of outcomes generated by spatially targeted investment strategies, especially those focused on transportation networks.

Initial attempts to use fully specified economic geography models in empirical⁶ studies have succeeded in testing and confirming some of the main theoretical results of NEG. However, they have failed so far to provide a more general analytical tool to assess spatial impacts of a broader range of policy options in the context of real economies. A common strategy is to estimate (a version of) an equilibrium wage equation derived from a structural model (e.g. Hanson, 1998; Redding, Venables, 2004; Brakman et al., 2006; Head, Mayer, 2006). The wage equation basically establishes a relationship between wages and access to markets and suppliers. It also reveals a trade-off between transportation costs and agglomeration.

Hanson (1998) estimated the structural parameters of the Krugman (1991) model of economic geography and showed that proximity to consumers is a key determinant of nominal wages in US counties. Market access was further explored in Redding and Venables (2004) in a context of a cross-section of countries. They added to Hansons' study in various ways. First, they expanded the concept of market access to include not only domestic but also foreign markets. Second, they

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^{5.} One may argue that, in the case of Colombia, positive indirect effects of geography related with its interactions with historical events swamp such direct contemporaneous negative effects associated with distance to the coast (see Nunn, Puga, 2007). In this paper, historical indirect channels are captured in the features of the calibrated database, which represents a "picture" of the existing economic structure of Colombia as a result of a series of historical events. The contemporaneous channels, related to market access and supply areas will be directly addressed in our analysis.

^{6.} Empirical studies consider actual data for real economies. The usual approach to rely on computer simulations to help theorists to explore property of the models has not shown any Document to exclusiv compromise with the use of actual data for real economies.

introduced the supply area effect in the determination of per capita income.⁷ They found evidence that both access to markets and sources of supply are important to explain cross-country variation in per capita income. In a similar fashion, Head and Mayer (2006) found evidence of a significant response of industrial wages to real market potentials in the EU regions. In the context of developing economies, Fally et al. (2008) found a strong (and robust) correlation between market access and wage differentials across Brazilian states. Furthermore, market access turned out to be, in that case, more important than supplier access.⁸ Also in Latin America, Vélez (2009) found evidence of the existence of a spatial wage structure in Colombia.

Brakman et al. (2006) went beyond the wage equation. Their main objective was to explore the link between the free-ness of trade⁹ and agglomeration for the EU regions. After having estimated the wage equation for the EU regions and shown that the existence of a spatial wage structure could not be rejected, they used their parameters estimates to calibrate a multi-region version of the NEG model to look at the relationship between different degrees of trade openness within the EU and the degree of agglomeration across the EU regions. Simulation results have shown that an increase in the free-ness of trade generates an increase in the economic importance of the core regions in the long-run (i.e., with re-location of workers and firms). However, their framework embedded a spatially restricted concept, in that trade outside EU was precluded. In a sense, foreign market access and foreign supply areas were disregarded. By ignoring foreign trade, the model fails to capture one of the main channels through which linkages operate, reducing the regional set that is relevant for properly implementing the concept of market access and supply areas.10

In this paper we look further at the link of free-ness of trade and the equilibrium distribution of activities. Regional integration is considered by reducing transportation costs between origin-destination pairs of Colombian domestic regions. We adopt the broader concept of market access and supplier areas which include both domestic and foreign trading regions. A fully specified interregional SAM, which includes flows of goods between origin-destination pairs of Colombian regions and an external region¹¹, is used to calibrate the spatial CGE model. Moreover, we

Market access is essentially a measure of market potential, measuring the export demand each intry faces given its geographical position and that of its trading partners; 'supplier accessite analogous measure on the import side, so is an appropriately distinguished by the will each court in the weight accessite in the second state of the second 7. country faces given its geographical position and that of its trading partners; 'supplier access' is the analogous measure on the import side, so is an appropriately distance weighted measure of the location of import supply to each country (op cit, pp 54-55).

^{8.} We will see in this paper that the relative importance of market access and supplier access is region-specific.

^{9.} A fall in trade costs, usually associated with reductions in transportation costs in the economic spatial system, corresponds to an increase in the free-ness of trade. 0

^{10.} Krugman and Livas-Elizondo (1996) showed the relevance of international trade in the context of an open spatial economy model.

^{11.} The external region is associated with the ports of exit and entry, so that we take care of the internal transportation costs related to international exports and imports. Document to excit

allow for labor and capital mobility introducing another driving force of spatial linkages.

The results are shown to be in line with NEG models, reproducing empirical regularities evidenced from wage equation estimates elsewhere. Not only access to domestic markets and suppliers are affected by regional integration of domestic regions, but also access to external markets. Furthermore, one important finding is that spatial hierarchy may play an important role to explain the resulting equilibrium distribution. The interplay of forces related to domestic and foreign markets may reveal a situation in which geography favors coastal areas. As transportation costs decline, the central region is positively affected; however, other regions with more privileged access to external markets may present an even better performance.

Also in line with NEG results, we show that different levels of economies of scale in the core region are linked to different distributional impacts, for a given level of integration. Weaker economies of scale favor the peripheral areas, resulting in a less concentrated distribution of activity.

After checking the fit of our model to NEG models, we proceed for a thorough decomposition of the results, from a spatial perspective of free-ness of trade. We borrow from the field of influence literature the idea of inverse important coefficients in order to identify strategic transportation links in the context of the Colombian interregional system (Sonis, Hewings, 1989). Given the nature of Johansenstyle CGE models, we can also expand the concept of measurement of the field of influence statistics in order to generate qualitative structures of influences based on different policy targets. Our results suggest a typology of regions based on the influence of forward and backward linkages. In other words, for some regions, accessibility to markets plays a major role to drive economic growth, while for others accessibility to suppliers is the main driver. Finally, there are also regions that equally benefit from forward and backward spatial linkages, and regions that are hampered by regional integration due to substitution effects. As will be seen, visualization techniques of such key transportation links provide a useful instrument for policy analysis.

Thic evaluation The paper is structured as follows. After this introduction, section 2 presents an overview of the CEER model, the spatial CGE model for Colombia to be used in the simulations. Section 3 presents the basic simulation - in which we look at an increase in economic integration among Colombian regions -, and puts the results into a NEG perspective. The idea is to check whether the "data generating process" embedded in the model mimics empirically confirmed theoretical results from NEG models. Section 4 proceeds with a thorough decomposition of the results of the basic simulation, based on structural sensitivity analysis techniques, which Document to exclusive use of the au considers the role played by changes in specific transportation costs. Concluding remarks follow.

1	Agriculture
2	Mining
3	Manufacturing
4	Construction
5	Transportation
6	Public administration
7	Other services

Table 1- Sectors in the CEER Model

2. The CEER Model

In this paper, we use the CEER¹² model, the first fully operational spatial CGE model for Colombia.¹³ We use an approach to incorporate the spatial structure that is similar to Haddad and Hewings (2005). Experimentation with the introduction of Marshallian scale economies and transportation costs provide innovative ways of dealing explicitly with theoretical issues related to integrated regional systems. The model used in this research contains over 35,000 equations in its condensed form, and it is designed for policy analysis. Agents' behavior is modeled at the regional level, accommodating variations in the structure of regional economies. Regarding the regional setting, the main innovation in the CEER model is the detailed treatment of interregional trade flows in the Colombian economy, in which the markets of regional flows are fully specified for each origin and destination. The model recognizes the economies of the 32 Colombian Departments and the capital city, Bogotá. Results are based on a bottom-up approach - i.e. national results are obtained from the aggregation of regional results. The model identifies 7 production/investment sectors in each region producing 7 commodities (Table 1), one representative household in each region, regional governments and one Central government, and a single foreign area that trades with each domestic region. Two local primary factors are used in the production process, according to regional endowments (capital and labor). Special groups of equations define government finances, accumulation relations, and regional labor markets. The CEER model qualifies as a Johansen-type model in that the solutions are obtained by solving the system of linearized equations of the model, following the Australian tradized tion. A typical result shows the percentage change in the set of endogenous variables, after a policy is carried out, compared to their values in the absence of such policy, in a given environment. The schematic presentation of Johansen solutions for such models is standard in the literature. More details can be found in Dixon and Parmenter (1996).

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Interregional linkages play an important role in the functioning mechanisms of the model. These linkages are driven by trade relations (commodity flows), and

^{12.} Centro de Estudios de Economia Regional del Banco de la Republica, Colombia. al Document to exclusi

^{13.} Full model description is available in an appendix.

factor mobility (capital and labor migration). In the first case, interregional trade flows are incorporated; interregional input-output relations are required to calibrate the model, and interregional trade elasticities play an important role (see Haddad, 2009).

2.1. CGE Core Module

The basic structure of the CGE core module is very standard and comprises three main blocks of equations determining demand and supply relations, and market clearing conditions. In addition, various regional and national aggregates, such as aggregate employment, aggregate price level, and balance of trade, are defined. Nested production functions and household demand functions are employed. For production, firms are assumed to use fixed proportion combinations of intermediate inputs and primary factors in the first level while, in the second level, substitution is possible between domestically produced and imported intermediate inputs, on the one hand, and between capital and labor, on the other. At the third level, bundles of domestically produced inputs are formed as combinations of inputs from different regional sources. The modeling procedure adopted in CEER uses a constant elasticity of substitution (CES) specification in the lower levels to combine goods from different sources. Given the property of standard CES functions, non-constant returns are ruled out. One can modify assumptions on the parameters values in order to introduce external scale economies of the Marshallian type. Changes in the production functions of the manufacturing sector¹⁴ in Bogotá region were implemented in order to incorporate non-constant returns to scale, a fundamental assumption for the analysis of integrated interregional systems. We kept the hierarchy of the nested CES structure of production, which is very convenient for the purpose of calibration (Bröcker, 1998), but we modified the hypotheses on parameters values, leading to a more general form. Non-constant returns to scale were introduced in the group of equations associated with primary factor demands within the nested structure of production. The sectoral demand for the primary factor composite (in region r), v, relates to the total output, z, in the following way: , with the technical coefficient a, and the parameter ρ specific to sector i in region r. This modeling procedure allows for the introduction of Marshallian agglomeration (external) economies, by exploring local properties of the CES function. The use of such pure or "Marshallian" external economies, which are external to individual firms but internal to the industry, provides a convenient framework for spatial CGE models, for increasing returns at the industrial level are compatible with competitive equilibrium. Furthermore, Abdel-Rahman and Fujita (1990) show that for descriptive analyses of spatial aggregates, external economy models often yield the same results to displacements from the original equilibrium as (appropriately designed) monopolistic competition models à la Dixit and Stiglitz (Fujita, Krugman 2004).

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^{14.} Only the manufacturing activities were contemplated with this change due to data availability nis Document to exclusiv for estimation of the relevant parameters.

The treatment of the household demand structure is based on a nested CES/linear expenditure system (LES) preference function. Demand equations are derived from a utility maximization problem, whose solution follows hierarchical steps. The structure of household demand follows a nesting pattern that enables different elasticities of substitution to be used. At the bottom level, substitution occurs across different domestic sources of supply. Utility derived from the consumption of domestic composite goods is maximized. In the subsequent upper-level, substitution occurs between domestic composite and imported goods.

Equations for other final demand for commodities include the specification of export demand and government demand. Exports face downward sloping demand curves, indicating a negative relationship with their prices in the world market. One feature presented in CEER refers to the government demand for public goods. The nature of the input-output data enables the isolation of the consumption of public goods by both the Central and regional governments. However, productive activities carried out by the public sector cannot be isolated from those by the private sector. Thus, government entrepreneurial behavior is dictated by the same cost minimization assumptions adopted by the private sector.

An important feature of CEER is the explicit modeling of the transportation services and the costs of moving products based on origin-destination pairs. The model is calibrated taking into account the specific transportation structure cost of each commodity flow, providing spatial price differentiation, which indirectly addresses the issue related to regional transportation infrastructure efficiency. Such structure is physically constrained by the available transportation network, modeled in a geo-coded transportation module (see Haddad, Hewing, 2005 for more details). Other definitions in the CGE core module include: tax rates, basic and purchase prices of commodities, tax revenues, margins, components of real and nominal GRP/GDP, regional and national price indices, money wage settings, factor prices, and employment aggregates.

The model is structurally calibrated for 2004; a rather complete data set for Colombia is available for that year, which is the year of the last publication of the full national input-output tables that served as the basis for the estimation of the interregional input-output database, facilitating the choice of the base year. Additional structural data from the period 2000-2004 complemented the database. The effort in the calibration process was concentrated in the compilation of the interregional SAM, which provided the information for the structural coefficients of the model. As for the behavioral parameters, most of them were taken from the uthor for the literature (see below).

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2.2. Structural Database

The CGE core database requires detailed sectoral and regional information about the Colombian economy. National data (such as input-output tables, foreign n i ^{9/ieursya}othentio trade, taxes, margins and tariffs) are available from the Colombian Statistics

Bureau (DANE).¹⁵ At the regional level, a full set of accounts was developed by the Colombian institute CEGA. These two sets of information were put together in a balanced interregional social accounting matrix. Previous work in this task has been successfully implemented in CGE models for Brazil and Colombia (Haddad, 1999; Jensen et al., 2004).

2.3. Behavioral Parameters

Parameter values for international trade elasticities were taken from estimates from Ocampo et al. (2004); regional trade elasticities were set at the same values as the corresponding international trade elasticities (Table 1). Substitution elasticity between primary factors was set to 0.5. Scale economies parameters, ρ s above, were set to one in all sectors and regions, except for the manufacturing sector in Bogotá, which was set to 0.8. The marginal budget shares in regional household consumption were calibrated from the SAM data, assuming the average budget share to be equal to the marginal budget share. We have set to -2.0 the export demand elasticities. Finally, we have assumed constant returns to bulk transportation, setting the parameter of scale economies in bulk transportation to one.

Further details of the model, including equation specification may be found in Haddad et al. (2009).

2.4. Closure

In order to capture the effects of regional integration, the simulations are carried out under a long run closure. There is no dynamics in the model. The simulations with the CEER model capture the effects associated with the static impact-effect question, i.e., given the structure of the economy, what-if questions can be addressed in a comparative-static framework. Short run and long run considerations differ in the way the equilibrating mechanisms are set through the closures specified. Structural changes are captured *only* through the evaluation of a re-allocation of resources. A main distinction between the short run and long run closures relates to the treatment Long run, policy changes are allowed to affect capital stocks. In addition to the assumption of interindustry and interregional immobility of capital, the short run closure would include fixed regional population and labor supply. fixed regional wage differentials, and fixed national real ways are allowed to affect and the supply fixed regional by the assumption. by the assumptions on wage rates, which indirectly determine regional unemployment rates. Labor is, thus, mobile only across sectors within the same region. On the demand side, investment expenditures are fixed exogenously - firms cannot reevaluate their investment decisions in the short run. Household consumption follows household disposable income, and real government consumption, at both JSEO

^{15.} Official statistics do not fully consider illegal activities in Colombia. n (Document to excit

regional and central levels, is fixed. Balance of payments has to adjust to changes in government deficit. Finally, preferences and technology variables are exogenous.

In the long run, the assumptions on interregional mobility of capital and labor are relaxed and a steady-state-type of solution is achieved, in which regional natural unemployment rates and regional aggregate rates of return are reestablished. Moreover, balance of payment equilibrium is reflected in the hypothesis of fixed share of trade balance in GDP. From a spatial perspective, in the long run the 're-location' effect becomes relevant; as factors are free to move between regions, new investment decisions define marginal re-location of activities, in the sense that the spatial distribution of capital stocks and the population changes.

The main differences from the short run are encountered in the labor market and the capital formation settings. In the first case, aggregate employment is determined by population change, labor force participation rates, and the natural rate of unemployment. The distribution of the labor force across regions and sectors is fully determined endogenously. Labor is attracted to more competitive industries in more favored geographical areas, keeping regional wage differentials constant. While in the same way, capital is oriented towards more attractive industries, equalizing rates of return across space. In the long run, the government deficit is set exogenously, allowing government expenditures to change.

3. Effects of Regional Integration

3.1. Basic Results

The basic experiment in this paper consists of the evaluation of an overall 1% reduction in transportation cost within the country. In other words, for every domestic origin-destination pairs, the usage of transportation margins is reduced by 1%. The simulations were carried out under a long run environment. We will focus on the effects on the allocation of economic activity, looking at the model's results for GDP growth. The idea behind this exercise is to assess potential efficiency gains in the transportation network associated with spatial integration issues.

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trade parameter on the spatial allocation of resources. In our case, we are able decompose the specific effects associated with transport cost reductions in and in a specific effects associated with transport cost reductions in and in a specific effects associated with transport cost reductions in and it is inward trade flows. This will preserve to decompose the specific effects associated with transport cost reductions in each origin-destination pair of regions, identifying also whether it is related to outward or inward trade flows. This will provide a detailed picture of the relative importance of market access and supplier access to regional performance.

For reference, Figure 1 depicts the spatial distribution of the results. There appears to be basically two spatial regimes, seemingly related to a coastal effect: geographical proximity to external markets seems to play a prominent role in driving the results. It is perceived a spatial shift of the relative benefits towards the Lart, Document to exclut coastal regions outside Bogotá – where a large part of the ports locate – and its



Figure 1 - Spatial Effects of Regional Integration on GRP Growth

immediate vicinity. This movement can be noticed through the analysis of the northwestward movement of darker colors in the map, as well as the dominance of white and lighter colors in the south-east. In other words, in some regions the effects of regional integration may be further hindered by additional spatial impediments in the form of higher transportation costs associated with the transfer of goods from the points of production to the ports of exit. As we will see in the next section, regions are positively affected by increasing market access and supply access, but may be hampered by trade deviation due to substitution effects associated with

rigure 2 reports more aggregate results for real GRP, considering Colombian macro-regions. Noteworthy is that Bogotá performs below the national average, suggesting that greater free-ness of trade within Colombia generates a less constitution of economic activity. The aforement in the above-average performance of the coastal regions, namely Caribe, Central Occidental and Pacífico. The Central Norte region, even though it does not have direct access to the coast, is able to explore its geographical advantage given by its intermediate position between Bogotá metropolitan area and the Caribbean.

Qualitative sensitivity analysis is carried out in order to grasp a better understanding on the role played by the introduction of external non-constant returns to scale in the modeling framework. More specifically, the goal here is to assess the role played by increasing returns in the manufacturing sector in Bogotá, the richest, Document to excit



Figure 2 - Macro-regional Effects of Regional Integration on GDP/GRP Growth

most industrialized region in Colombia and for which there is evidence that it is the focal point of agglomeration economies in the country (Haddad et al. 2009). For instance, a crude indicator using the DANE data shows that, while Bogotá's share in manufacturing value added in the period 2002-2005 was 31.5%, the region's share in total manufacturing employment was 23.1%.

Theoretical results from the NEG literature suggest that there is a fundamental trade-off between transportation costs and increasing returns to scale (IRTS). If this is the case, in a core-periphery interregional system, the core region, which hosts the increasing-returns sector, can potentially further benefit from improvements in the transportation sector by exploiting scale economies. Moreover, the stronger the scale economies exhibited by the core region, the better its expected relative performance. We check these results using the CEER model with a special set of values for the scale economies parameters. We assume constant returns in every sector in every region. The only exception is the manufacturing sector in Bogotá, for which we consider an interval in the IRTS curve, ranging from high increasing returns to decreasing returns to scale in the manufacturing sector. A series of simulations is run for various values of the parameter in the assumed interval. Results are presented in Figure 3 Theoretical results are partially confirmed in the empirical experimentation with the CEER model. As it becomes evident from the results for Bogotá, the further down the IRTS curve, the better the region's performance in terms of GRP growth. However, as noticed before, Bogotá performs below the national average.

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The role of spatial dependence is also revealed in Figure 3 On one hand, Central Norte, Central Sur and Nuevos follow the same pattern of Bogotá, revealing dependence and complementarity with it. As economies of scale fade away, their relative performance is also hampered. On the other hand, Caribe, Central Occidental Documento exclu



Figure 3 - Effects of Regional Integration under Different Levels of Agglomeration Economies in Bogotá

and Pacífico, the coastal regions, go in the opposite direction, indicating spatial competition with Bogotá. In addition, looking at the slopes of the curves within the groups of regions defined above, stronger dependence with Bogotá is revealed by the Central Norte, while stronger competition with Bogotá seems to be with the Pacífico region.

It is clear in this exercise that the modeling strategy pursued is grounded on a set of key assumptions (e.g. micro foundations, general equilibrium, increasing returns to scale and transportation cost) intended to replicate theoretical results from NEG models in a more general framework ably used for policy assessment purposes. Such preselection shapes the policy analysis in a way that one would expect the model to reproduce empirical regularities evidenced from tests of equilibrium equations derived from structural NEG models. To check that, we used the model results to capture the embedded relationship between regional wages and market access and supplier access in a context of regional integration. We look at the wage equation considering displacements from the original equilibrium, i.e. we regress the results for changes in regional wages associated with the reduction in transportation costs on the results for changes in regional exports and regional imports, both in volumes. According to the econometric results presented in Table 2, changes in domestic (and foreign) sales and purchases explain 96 percent of the variation of wages across Departments in the CEER model results. Document to exclusive use of the

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Dependent variable: Regional wage								
Variable	Coefficient	Std. Error	t-Statistic	P-value				
Constant	-0,0098	0,0004	-24,3539	0,0000				
Interregional exports	0,1940	0,0425	4,5646	0,0001				
International exports	0,2535	0,0207	12,2192	0,0000				
Interregional imports	-0,1176	0,0321	-3,6591	0,0010				
International imports	0,1636	0,0372	4,4013	0,0001				

Table 2 - Structural Analysis of Regional Wages

Obs.: Variables in percentage-change form

R-squared = 0.9613

4. Analytically Important Transportation Links

In order to address the issue of identification of the analytically most important structural links in generating CGE model outcomes for the case where a CGE model has been linked with a stylized network-based transportation system, we proceed with a thorough decomposition of the results of simulations considering the role played by various small changes in specific transportation costs. These incremental changes are associated with (a group of) coefficient changes computed from the information contained in the initial solution. In other words, we explicitly take into account the role played by each transportation link in generating the model's results. Thus, one can identify the fields of influence of various structural links associated with specific policy outcomes.

For each transportation link, we calculate its contribution to specific outcomes, considering different dimensions of regional policy. Impacts on regional efficiency are considered. We look at the effects on regional efficiency, through the differential impacts on GDP growth for seven Colombian macro regions (see Annex), and for the country as a whole (systemic efficiency). Scaffolding of the spatial results is considered in order to evaluate analytically important transportation links that optimize specific policy goals.

To obtain a finer perspective on the analytically most important transportation links that ks for optimizing a given policy target, we decompose the results into register of gion links. Key links based on their influence to tional GDP growth links for optimizing a given policy target, we decompose the results into region-toregion links. Key links based on their influence on each policy strategy (regional/ national GDP growth) are highlighted and mapped in Figures 4-11. Notice that the set of most influential transportation links varies according to different (spatial) policy targets. For instance, growth in Bogotá associated with regional integration seems to be more influenced by improved access to suppliers while Caribe presents . lin Document to exclusive use of a more market-oriented growth based on improved forward linkages.



Figure 4 - Analytically Important Transportation Links Based on Systemic Efficiency: Colombia

Figure 5 - Analytically Important Transportation Links Based on Regional Efficiency: Bogotá





Figure 6 - Analytically Important Transportation Links Based on Regional Efficiency: Caribe

Figure 7 - Analytically Important Transportation Links Based on Regional Efficiency: Pacífico





Figure 8 - Analytically Important Transportation Links Based on Regional Efficiency: Nuevos Departamentos

Figure 9 - Analytically Important Transportation Links Based on Regional Efficiency: Central Sur





Figure 10 - Analytically Important Transportation Links Based on Regional Efficiency: Central Occidental

Figure 11 - Analytically Important Transportation Links Based on Regional Efficiency: Central Norte



		Destination				
		r	R			
Origin	r	0	$MA_r = \sum_q y_{sq}^r = y_{s\bullet}^r$, for $s=r$			
	R	$SA_r = \sum_{s} y_{sq}^r = y_{\bullet q}^r$, for $q = r$	$SE_r = \sum_{s} \sum_{q} y_{sq}^r = y_{\bullet\bullet}^r$, for s,q ¹ r			

Figure 12 - Summary Matrix of Results for GRP Effects

r = study region; R = rest of the country

4.1. Summary

This section summarizes the simulation results focusing on the implications of regional integration for regional growth. We present a visualization technique that provides an opportunity to explore regional characteristics of the Colombian economy, reflecting the spatial economic phenomena of backward and forward linkages specifications in a fully integrated interregional system. The results are presented in a way that helps identifying the different patterns of spatial integration from a region's own perspective.

The basic information used to build the HBC¹⁶ figure below is drawn from matrices of results that contain, for each *Departamento*, the GRP effect of reductions in transportation costs for every origin-destination pair in the Colombian system. A typical element of this matrix is y_{sq}^r the percentage change in GRP in region r, associated with a 1% reduction in transport costs from s to q.

It is possible to aggregate this information (Figure 12) in such a way that we obtain three summary measures reflecting the isolated effects of increasing the region's direct access to markets (MA_r) ; increasing direct access to suppliers (SA_r) ; as well as the indirect effects associated with transportation costs reductions outside the region (SE_r) . Notice that we do not consider changes in intraregional transport costs; hence the zero effect in the first cell.¹⁷

evaluation

In order to get comparable results for each region, it is necessary to normalize the information presented in Figure 12 Then, we consider the values of MA, SA, and SE as vectors, and proceed with a normalization based on the sum of the vector norms (which will represent, as a consequence, the overall effect on GRP Dooument to exclusive use (

^{16.} HBC stands for hinge-based-circle.

^{17.} For each matrix of results, the main diagonal is zero.



Figure 13 - Schematic Representation of the HBC Figure

of the reduction in transportation costs). It is important to notice that the sign of the normalized effects remains the same, as we are basing it on the norm of each vector.

The normalized vectors for MA and SA are represented in a Cartesian plan, over their respective axes (MA is represented in the x-axis and SA is in the y-axis), and their vector sum results in a vector that defines the direction and the sense in which the point will be plotted. The following step is to take the intersection of this resultant vector and a circumference with radius one and center in the origin of the Cartesian plan defined before. Departing from this so defined point, we plot the normalized vector of the SE (with the same direction of the resultant vector mentioned above). Positive values for SE are represented as pointing to the center of the circumference, and, thus, fall inside the circle. Negative values, on the other hand, fall outside the circle. This is so that the winning regions, regarding the SE effect, are located inside the circle.

The steps mentioned before produce the areas represented in Figure 12 with all kinds of signs combinations between the three effects. Taking the data from the Colombian system, we obtain a comparison of the importance of each effect to the regions, what allows us to better understand the Colombian interregional system? One last piece of information represented in Figure 13 refers to the total effect on GRP: for positive regional effects of regional integration, the symbol representing the region is a (blue) triangle turned up, and in the opposite case, is an upside-down (red) triangle. We end up with the HBC figure (Figure 13) for the Colombian case.

evaluation

As can be seen from inspection of Figure 14, for most regions we find positive growth effects related to better access to markets and suppliers, and negative effects associated with the substitution effect.¹⁸ In other words, as overall transportation Documentoexclusive

^{18.} Regions in the area of MA(+), SA(+), SE(-).



Figure 14 - Typology of Regions According to their Growth-orientation with Increasing Integration

costs go down, a region tends to be directly benefited by better accessibility to its trade partners, but is hampered, through trade deviation, by transportation improvements related to trade links outside its direct domain. Moreover, regional integration would generate positive overall growth to most Colombian regions, with the exceptions associated with more peripheral, less integrated remote areas.

When examining regions, one by one, we find that the general pattern described above does not tell the whole story. Let us consider, for instance, the four Departamentos associated with the main Colombian cities, namely, Bogotá, Antioquia (Medellín), Valle (Cali), and Atlántico (Barranquilla). A closer inspection of the HBC figure shows that: (i) Bogotá presents strong supplier-growth-orientation; (ii) Antioquia is equally benefited by access to markets and suppliers; (iii) Valle (and most regions) presents market-growth-orientation; and (iv) Atlántico, besides presenting supplier-growth-orientation, is also benefited indirectly by transportation improvements among external regions. the author

evaluation

5. Final Remarks

ing ai igh it ma 26 etclus Documento In this paper, we explore features of a modeling approach in order to reinforce policy relevance of NEG models. Even though it may be argued that Cournot's

problem is still to be resolved in the context of the NEG, spatial CGE models place an opportunity to explore its characteristics to fill the gap between theory and practice. It has been argued elsewhere that NEG models, founded on satisfactory economic theory, that are evolving into more broadly based spatial CGE model, provide a promising alternative to spatial impact assessment of economic policies.¹⁹ Moreover, implementation of high potential spatial CGE models appears to be easier than expected (Oosterhaven, Knaap, 2003; Giesecke, Madden, 2006).

The results provided are encouraging in the sense that the issues, while difficult, are not insurmountable. The challenges to competitive equilibrium in the spatial economy presented by the NEG remain largely untested. The present paper departs from Haddad and Hewings (2005) and offers one approach to a goal of narrowing the gap between theory and empirical application. The Colombian economy, sharing features of most developing countries, presents a further challenge; the non-uniformity of the spatial distribution of resources and population, the glaring disparities in welfare across regions, and the presence of a hegemonic economy, in Bogotá, that renders traditional CGE modeling of limited value.

The results confirms that it is possible to handle increasing returns to scale, to address issues of asymmetric impacts of transportation investment and to approach the problems of more flexible functional forms, uncertainties about data and parameter estimates in ways that are tractable and theoretically defensible. The paper offers the perspective that there is a need, perhaps, to pause and take stock of the current state of the art in spatial CGE modeling and to pursue further some of the lines of inquiry addressed in this work, trying to reach a balance between rigor and relevance. As the results are shown to be in line with NEG models, reproducing empirical regularities evidenced from econometric estimates, heuristic validation of the model may be achieved.

In this sense, modeling integration becomes a major goal to pursue. Some of the shortcomings of spatial CGE models might be suppressed by inserting a core CGE in a broader modeling framework. Isard's vision of integrated modeling, which anticipated the proposals reported in Isard and Anselin (1982), provided a road map Ing uner limitations!), if adequately addressed in the context of NEG theoretical developments, spatial CGE models are potential candidates for the core subsystem in an integrated spatial system. -m for the acader

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^{19.} See Oosterhaven and Knaap (2003).

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Appendix





De	partamentos	Macro-regions		Departamentos	Macro-regions	
D1	Antioquia	Central Occidental	D18	Norte Santander	Central Norte	
D2	Atlántico	Caribe	D19	Quindío	Central Occidental	
D3	Bogotá D. C.	Bogotá	D20	Risaralda	Central Occidental	
D4	Bolívar	Caribe	D21	Santander	Central Norte	
D5	Boyacá	Central Norte	D22	Sucre	Caribe	
D6	Caldas	Central Occidental	D23	Tolima	Central Sur	ation
D7	Caquetá	Nuevos	D24	Valle	Pacifico	131110
D8	Cauca	Pacifico	D25	Amazonas	Nuevos	ر [©]
D9	Cesar	Caribe	D26	Arauca	Nuevos &	
D10	Córdoba	Caribe	D27	Casanare	Nuevos 🔗	
D11	Cundinamarca	Central Sur	D28	Guanía	Nuevos 💉	
D12	Chocó	Pacifico	D29	Guaviare	Nuevos	
D13	Huila	Central Sur	D30	Putumayo	Nuevos	
D14	La Guajira	Caribe	D31	San Andrés y Provid	Nuevos	
D15	Magdalena	Caribe	D32	Vaupés 💍	Nuevos	
D16	Meta	Nuevos	D33	Vichada	Nuevos	
D17	Nariño	Pacifico		SINO		
			30	to etcil		
			Docum	ert.		

Colombian Regions