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Measuring Market Conduct in the Brazilian Cement Industry: A Dynamic Econometric Investigation

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Abstract Indirect assessments of market conduct have become widespread in the New Empirical Industrial Organization—NEIO literature. Recently, Steen and Salvanes (1999, Int J Ind Organ 17:147–177) provided a flexible dynamic econometric formulation of the approach advanced by Bresnahan (1982, Econ Lett 19:87–92) and Lau (1982, Econ Lett 10:93–99). The present paper considers a similar approach applied to regional cement markets in Brazil under more favorable data availability, and attempts to address part of the concerns that usually emerge with respect to the NEIO literature. In particular, issues pertaining to structural stability and the control for the number of competing firms are addressed. The evidence clearly indicates non-negligible and distinct market power in different regions and also distinct conduct patterns in the short and long run.

Keywords New Empirical Industrial Organization · Error-correction mechanism · Cement market

JEL Classification L110 · L130

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1 Introduction

Empirical assessments of market conduct in the context of unobservable marginal costs have become increasingly prevalent in the empirical literature over the last few years. In these papers, the identification of the conduct parameter is primarily attributed to two factors: the responsiveness of prices to changes in the elasticity of demand, and shifts in costs [see, e.g., Bresnahan (1989) for an early account on the so-called New Empirical Industrial Organization (NEIO)].

Questions have arisen, however, about the accurateness of the indirect conduct measurement. At an empirical level, Aiginger et al. (1995) and Steen and Salvanes (1999) defended the possible gains of implementing flexible and dynamic empirical specifications despite the usual underlying static oligopoly framework. These approaches attempt to capture short-run dynamics and implicitly account for dynamic effects that could be related to habit formation in demand and to adjustment costs in supply.

The purpose of the present paper is to consider an empirical application of a NEIO model in terms of a dynamic econometric framework, albeit utilizing a context that is more favorable in terms of data availability, while acknowledging the potential concerns that are present in the literature. These concerns, as specified in the work of Corts (1999), Sexton and Zhang (2000), Puller (2007) and Kim and Knittel (2004), range from the empirical definition of the relevant market to theoretical considerations over the validity of the estimated conduct parameters.

These issues are addressed in this paper in the context of regional cement markets in Brazil. Specifically, the issues considered pertain to structural stability and to controls for the number of competing firms in each market. The traditional homogeneous oligopolies for cement have been studied extensively (see, e.g., Lima 1995; Steen and Sørgard 1999; Rosenbaum and Sukharomana 2001; Röller and Steen 2006; la Cour and Møllgaard 2003). Nevertheless, the consideration of NEIO models in the context of developing economies has received scant attention in the literature.

This paper is organized as follows: Sect. 2 introduces the empirical model, providing a framework for understanding some questions surrounding the NEIO literature. Section 3 provides a detailed description of the Brazilian cement sector. Section 4 presents the empirical analysis in terms of data construction, the formulation of the empirical model, and related estimates. Section 5 is composed of closing comments and recommendations for future research.

2 NEIO Models: Conceptual Aspects

A typical approach for identifying the conduct parameter in oligopolistic markets relies on the responsiveness of prices to changes in the elasticity of demand (see, e.g., Bresnahan 1989). A starting point for our discussion is the conception of a generic perceived marginal revenue that depends on the conduct parameter λ as given by $\mathrm{MR}(\lambda) = p + \lambda Q \mathrm{d}p/\mathrm{d}Q$, where p and Q, respectively, denote price and quantity. Under profit maximization, such an expression is equated to the marginal cost, and three important cases arise as particular cases.[1] In the first case, if $\lambda = 1$, it corresponds to a fully collusive situation. Secondly, if the other polar case occurs, $\lambda = 0$ would hold for a competitive market. Thirdly, the intermediate range of the conduct parameter would include different degrees of imperfect competition; in particular $\lambda = 1/n$ would be consistent with a symmetric Cournot oligopoly with n firms. The well established argument for the identification of the conduct parameter in a homogeneous oligopoly is outlined by Bresnahan (1982) and Lau (1982). They define empirical methods based on responses to variation in the elasticity of demand that rely on the rotation of the demand curve for identification of the conduct parameter.

A departure from the majority of the static versions of the NEIO model is provided by Karp and Perloff (1989), Deodhar and Sheldon (1996), Aiginger et al. (1995) and Steen and Salvanes (1999). The last two works, in particular, consider a flexible (error correction) dynamic specification for non-stationary variables. This paper follows Steen and Salvanes (1999) specification.

At a conceptual level, it is important to stress that existing NEIO models essentially rely on static oligopoly models. The flexible specification implied by the empirical dynamic model is therefore mostly justified on the grounds that it has the capability for properly capturing short-run departures from the long-run equilibrium, as it does not rely on a strict adherence to the underlying (static) theoretical model in the context of non-stationarity.

The present approach incorporates a dynamic version, as the dynamic model is hypothesized to provide more information about the market than does a static model. As such, a lagged structure in the empirical model appears sensible. Lagged values of price and quantity provide information about the current values of the variables. Following the Steen and Salvanes (1999) ECM model, the modified demand becomes:

$$\Delta Q_t = \alpha_0 + \sum_{i=1}^{k-1} \alpha_{Q,i} \Delta Q_{t-i} + \sum_{i=0}^{k-1} \alpha_{p,i} \Delta P_{t-i} + \sum_{i=0}^{k-1} \alpha_{Z,i} \Delta Z_{t-i} + \sum_{i=0}^{k-1} \alpha_{\mathrm{PZ},i} \Delta \mathrm{PZ}_{t-i} + \gamma^* \left[Q_{t-k} - \theta_p P_{t-k} - \theta_Z Z_{t-k} - \theta_{\mathrm{PZ}} \mathrm{PZ}_{t-k} \right] + \varepsilon_t \quad (1)$$

where $\theta_j = \frac{\alpha_j^*}{\gamma^*}$, and $j = P, Y, Z, \mathrm{PZ}$ with P, Y, and Z respectively indicating price, and two classes of demand shifters, whereas the variable PZ reflects an interactive term associated with the rotation of the demand necessary for the identification of the conduct parameter. The existence of an error correction representation follows the Granger (1981) representation theorem. The result legitimates such a representation in the context of non-stationary cointegrated $I(1)$ variables. In brackets one observes the error correction term given by the Bärsden (1989) transformation and θ_p indicates the long-run effect of P on Q.

[1] If one solves the aforementioned first-order condition in terms of λ, one will be able readily to interpret it as the Lerner index adjusted for the price elasticity of demand, as is emphasized, for example, by Genesove and Mullin (1998).

The supply relationship is transformed to:

$$\Delta P_t = \beta_0 + \sum_{i=1}^{k-1} \beta_{p,i} i \Delta P_{t-i} + \sum_{i=0}^{k-1} \beta_{Q,i} \Delta Q_{t-i} + \sum_{i=0}^{k-1} \beta_{W,i} \Delta W_{t-i} + \sum_{i=0}^{k-1} \lambda_i \Delta Q^*_{t-i}$$
$$+\psi^* \left[P_{t-k} - \xi_Q Q_{t-k} - \xi_W W_{t-k} - \lambda_L Q_{t-k}\right] + \eta_t \quad (2)$$

where

$$Q^*_i = \frac{Q_t}{(\theta_p + \theta_{PZ} Z_t)},$$

and

$$\lambda_L = \frac{\lambda^*}{\psi^*}, \quad \xi_Q = \frac{\beta^*_Q}{\psi^*}, \quad \xi_W = \frac{\beta^*_W}{\psi^*}.$$

The price elasticity of demand (ε_{pp}) and the income elasticity of demand (ε_{py}) are calculated in the usual way:

$$\varepsilon_{pp} = [\alpha_p + \alpha_{pz} \bar{Y}] \cdot [\bar{P}/\bar{Q}] \quad (3)$$

and

$$\varepsilon_{py} = [\alpha_p + \alpha_{pz} \bar{P}] \cdot [\bar{Y}/\bar{Q}]. \quad (4)$$

The short-run conduct parameter λ_0 (henceforth denominated by λ_S) and the long-term parameter λ_L appear in Eq. 2. The rationale is that there is a static measure of market power, with an error correction mechanism that drives the market towards equilibrium in the long run. Furthermore, ψ^* is the adjustment parameter of the supply relation, where 0 indicates a permanent deviation from the short-run equilibrium whereas 1 indicates an instant adjustment

The empirical analysis follows three steps:

(a) it considers unit root tests and verifies the prevalence of cointegration in the case of $I(1)$ variables, where the lag structure of the VAR system should be justified in terms of some established criterion (in our case, the Akaike information criterion);
(b) it generates (lagged) residuals of the VAR estimation to be used as an error correction term in the related representation (assuming cointegration); and
(c) it estimates Eqs. 1 and 2 by means of three-stage least squares. The procedure contrasts with the previous literature that employed two-stage least squares with the risk of ignoring potential correlations between the errors of the two equations.

2.1 Critiques of the NEIO Models

Acknowledging prevailing critiques of the NEIO can be useful when pursuing a careful application of these models. Five major concerns are discussed below. These concerns were addressed by Corts (1999), Sexton and Zhang (2000), Puller (2007), and Kim and Knittel (2004), among others.

(i) *Weak economic theory foundation*
Since NEIO models can be related to a conjectural variations framework, an indirect critique of NEIO models is that "one aspect that has been discussed critically pertains to the conceptual underpinning or lack thereof provided by the conjectural variations framework."[2] A partial caveat to that critique is based on the work of Cabral (1995), who has shown that the conjectural variation model can be seen as a reduced form of a simultaneous quantity-setting Cournot supergame in the case of linear demand. In other words, under certain conditions the conjectural variation framework provides an approximation of a dynamic model.

(ii) *No treatment of structural changes such as technology*
One very pertinent critique (Sexton and Zhang 2000) is that most NEIO studies have relied on annual data. To gain enough data points, in some cases NEIO models have been estimated with data that span 30 years, without allowing for structural changes or even using simple dummy variables. Again, this is not a critique of NEIO models per se, but of the specification of empirical models used in industrial economics.

(iii) *Difficulties in defining the relevant market definition*
Another critique that is not limited to NEIO models is that of a relevant market definition. Schroeter (1988), for instance, defines the beef market as national, even though cattle are seldom shipped as far as 300 miles (Sexton and Zhang 2000).

(iv) *Ad hoc hypothesis on demand and supply variables*
Most NEIO estimations were undertaken in the context of one-sided market power, which assumes that market power occurs only on one side of the market, while the other side behaves competitively. This may not be the case; market power can exist on both the demand and supply sides. Some studies (Schroeter et al. 2000; Gohin and Guyomard 2000) have dealt with this issue by using models that allow for market power on the demand and supply sides.

(v) *Inconsistency of the conduct parameter*
Corts (1999) has put forth the most challenging critique of NEIO models: Corts observed that any structural change to the demand or supply variables would make the conduct parameter correlated with the instrumental variables that are necessary for the estimation of the model. Furthermore, Wolfram (1999), Corts (1999), and Puller (2007) show that if the firms are efficiently colluding, the estimated model is misleading since there is no simultaneous quantity setting. Therefore, the estimated conduct parameter would understate the true conduct parameter. As a result, it would only be useful to test the model if the market behaves competitively ($\lambda = 0$), monopolistically ($\lambda = 1$), or would have a

[2] See Sexton and Zhang (2000, p. 19).

symmetric Cournot-equilibrium ($\lambda = 1/n$, where n is the number of firms on the market).

3 The Cement Oligopoly

3.1 The Brazilian Cement Market

The cement industry is frequently used in empirical studies because it is considered an archetype of a homogenous oligopoly. Our examination of the Brazilian cement industry allows for comparisons with the results of many other studies. In fact, cement is almost completely a homogeneous product, and therefore allows for a simple specification of the demand function and supply relationship.

Cement production involves large distribution costs; 94.5% of the cement consumed is produced within a 300-mile radius (Rosenbaum and Sukharomana 2001). Cement also has a short shelf life. Thus, it does not allow for large inventories, which makes market interactions much more rapid, and quantity setting is the norm for a firm's decision. The cement industry is mature, with few technological improvements; the last important improvement was the introduction of the dry production process in the 1970s (Teixeira et al. 2003). Excess capacity seems to prevail in the different regions at all times and can constitute an important mechanism for establishing an entry barrier to new competitors, based on theoretical models such as Dixit's (1980).[3]

An aggregate CR4 index, however, would provide little information on the true market structure due to the spatial distributions of firms and markets. Brazil is the fifth largest country in the world, and cement has substantial distribution costs. Brazil has five major regions—Southern, Southeast, Northern, Northeast, and Midwest. Not every firm is present in every region, and for the purposes of this paper, we will assume that the relevant market is a regional one, and we base it on a Chow poolability test.[4] It should be noted that data were adjusted to account for inter-regional shipments.

Table 1 reveals the spatial distribution of Brazilian firms and industrial plants. Although the data are only for 2006, this distribution has been the same for the last 10 years, with no new entries or exits in the regional markets. The regional markets are very different, especially due to different market sizes. The Southeast, which is the biggest market, is where most of the Brazilian GDP is concentrated and where cement consumption is the highest (over 50% of the total Brazilian consumption each year), while the Northern region is Brazil's largest region, accounting for 45% of the country's land mass, but this region's cement consumption is less than 5% of the total Brazilian consumption for every year. We can also safely assume that there is no market power on the demand side (Cunha and Fernandez 2003). Vertical integration is not a relevant concern and is mainly used to reduce costs in the few instances it happens (Teixeira et al. 2003).

[3] Available aggregate figures for 2006 indicate that production represents only 63.17% of capacity. According to the producers' association (Sindicato Nacional da Indústria de Cimento—SNIC), the pattern of substantial excess capacity prevailed over time and across regions.

[4] This is supported by a vast literature on the Brazilian cement market (see, e.g., Lima 1995; Teixeira et al. 2003).

Table 1 The Brazilian national cement market—2006

Region	Number of firms	Largest producer as a % of market	Number of industrial plants
Northern	1	100.00	3
Northeast	5	28.81	13
Midwest	4	43.81	6
Southeast	8	29.19	28
Southern	5	51.05	7

SNIC (2006)

3.2 Comments on the Critiques

Although most critiques are not limited to NEIO models, they are still pertinent to the empirical models estimated in this paper. We believe that the sector we chose, the Brazilian cement market, allows a more favorable application of the NEIO framework. The concerns related to two critiques can be somewhat minimized through (a) the use of monthly data, which is the first choice for empirical estimation, and (b) the lack of major structural changes to the market, which allows for an unbiased estimation.

In relation to the relevant market critique, there is support in the literature for a Brazilian regional market. The data are also adjusted for imports and cross-regional shipments.[5] The exercise of market power is clearly one-sided, with a scattered demand that only allows market power on the supply side. Furthermore, the functional forms used in estimation, all linear, are supported by Genesove and Mullin (1998).

Corts' (1999) critique is that there may be a correlation between the conduct parameter and the instrumental variables used in the estimation. This would transform the conduct parameter into an endogenous variable, and thus it would not be explicitly identifiable. What we propose is a structural change test to identify changes (if any) in the demand function and supply relation that would lead to biases in the estimation. The rationale is that if the conduct parameter is exogenous and constant, no structural changes will occur in the market, and the conduct parameter will remain identifiable and unbiased. The main theoretical critique, also based on Corts (1999) and others, regarding the validity of the conduct parameter, is more difficult to address. It involves theoretical aspects of industrial economics models, which are beyond the scope of this work. For simplicity, it is assumed that conjectural variation models are a valid way of estimating market power.

4 Empirical Analysis

4.1 Data Construction

The essential ingredients of any NEIO study are price, quantity, and demand and cost shifters. Prices for cement and relevant inputs in each state were obtained from the Brazilian statistical bureau (SIDRA-IBGE) and Getulio Vargas Foundation, whereas

[5] Salvo (2007) analyzes the possibility that imports may restrict market power in the Brazilian cement market. In the present work the data are already adjusted for imports, and if imports play a role the indirect conduct parameter would be sensitive to it.

quantities from each state were obtained from the Brazilian manufacturers' association (Sindicato Nacional da Indústria do Cimento—SNIC). The data span 16 years (1991/2006), with 204 data points for the raw data. The apparent consumption data were achieved by calculating the shipment of cement within a region, plus shipments received from other regions, plus imports. The data for the 2001–2006 period were already properly adjusted, whereas for the 1991–2000 period we needed to add imports (with data from SECEX—Trade Secretary of the Ministry of Industry and Development). The descriptive statistics are presented in Appendix 1. Relevant markets were treated as regional, therefore aggregations were undertaken. The description of the variables is presented below:

Q: log of consumption of Portland cement in 10^3 tons for the given region. The quantity in each region is readily obtained from state figures;

P: log of price of the Portland cement (CP-32 50 kg). The regional price is obtained as a weighted average of the median price of each state where the weights are given by the quantities. The prices are deflated by the general price index (IGP from IBGE).[6]

W_i: the cost shifters for cement production: wages (W_1), the price of calcareous materials (limestone) (W_2), the price of sand used in cement production (W_3), and energy prices (W_4) were all considered in terms of their logs. Wages refers to the hourly wage of the cement industry worker. Calcareous materials and sand are prices per kilogram, and energy is a proxy of fuel and diesel oil.

Y: log of index for economic activity (Getulio Vargas Foundation).[7]

Z: log of index for the construction industry activity (IBGE).

4.2 Empirical Model and Results

Several tests were undertaken before the estimation of the model. Tests for unit roots revealed that the variables were $I(1)$ processes. Cointegration tests were also performed to ensure that an ECM formulation was possible. A separability test was necessary since Lau's (1982) impossibility theorem shows that the conduct parameter can be identified only if the demand is separable. A test to determine the lag of each variable was also performed based on Akaike (1979).[8] A Chow poolability test was performed [following Baltagi (2001), and, in the case of 3SLS, Razmi and Blecker (2008)]. The null hypothesis of poolability was rejected, and we conclude that regions should not be pooled together; hence the estimation of separate regional markets is valid. All results are presented in Appendices 1–5.

Finally, taking into account Corts' critiques, two structural change tests have been used: the regular Chow test and the recursive Chow test. The first test separates the T observations in half, estimates two separate demand functions, and tests for changes

[6] Therefore the dependent variables in the demand and supply relation equations are growth rates as given by the difference in logs for the related raw variables.

[7] The model can be estimated with only one variable representing the Z variable (Steen and Salvanes 1999). We chose another demand variable, Y, to improve the estimation, based on previous studies (Steen and Salvanes 1999; Alexander 1988).

[8] We suppress Akaike tests results for conciseness but could readily provide the relevant results upon request.

Table 2 Results for the two Chow structural change tests

Region	Regular Chow test		Recursive Chow test	
	F-test	p-value	F-test	p-value
Northern	0.012	1.000	0.000	0.994
Northeast	0.011	1.000	0.000	0.988
Southeast	0.000	1.000	0.000	0.999
Southern	0.002	1.000	0.000	0.994
Midwest	0.000	1.000	0.000	0.998

in the structure. The second test is more encompassing in nature: First it estimates the demand function with n observations, with subsequent estimations of the demand function with $n + 1, n + 2, \dots T$. In both cases an F-test statistic was used with an associated probability of structural stability. As shown in Table 2, the demand is structurally stable for both tests. The estimated conduct parameter can be considered an exogenous variable and is therefore an unbiased estimate of the average market-power of regional Brazilian cement market firms.

All of the tests confirmed that estimation of the model was viable since the variables were separable, had unit roots $I(1)$, and cointegration prevailed. The relevant estimation results are summarized in Table 3.

The two main parameters are λ_S and λ_L, and respectively denote the short-run and long-run conduct parameters. As shown in Table 3 the average market-power found is the average result of the firms' behavior in the market in the period that was considered. Variables ε_{pp} and ε_{pz} are the price elasticity and income elasticity of demand, respectively. ψ^* is the adjustment parameter. The Cournot value is a comparative measure of the conduct parameter from symmetric Cournot oligopoly, $1/n$, where n is the number of firms.

Two preliminary conclusions can be drawn from the model: The first conclusion is that the conduct parameters are different in each region, which makes it clear that there is no national market. The second conclusion is that for most regions conduct is correlated with the number of firms and industrial plants—more firms and industrial plants imply that firms behave, on the average, more competitively. The results typically indicate a significant departure from perfect competition, though conduct appears to be distant from a collusive pattern.

The evidence consistent with the Cournot equilibrium is present in the intervals for the conduct parameters of the Northeast and Midwest regions. This result is striking as it provides strong empirical support for Cournot behavior in these markets. Furthermore, the market where firms behave more competitively is the Southeast region. Small conduct parameters were expected in this region since it is where the most firms are present. Nevertheless, non-negligible market power is still detected as indicated by the related t-statistic for the null hypothesis of a zero conduct parameter. As the Southeast is the richest region of Brazil, it naturally attracts more intense competition, but market power still prevails.

To test for the Cournot equilibrium in the Northeast and Midwest regions, we formulated a simple t-test [following Steen and Salvanes (1999)] with the null hypothesis $H_0 : \lambda = 1/n$ and $H_1 : \lambda \neq 1/n$. At a 5% significance level we accepted the H_0

Table 3 Relevant results of static and dynamic versions of a NEIO model applied to the regional cement markets in Brazil

	Northern	Northeast	Southeast	Southern	Midwest
λ_S	0.322	0.159	0.030	0.287	0.172
St. error	0.172	0.101	0.003	0.090	0.063
p-value	0.031	0.058	0.000	0.001	0.003
λ_L	0.562	0.233	0.038	0.224	0.351
St. error	0.182	0.121	0.004	0.014	0.103
p-value	0.001	0.027	0.000	0.000	0.000
ε_{pp}	−0.255	−0.341	−0.565	−0.162	−0.549
ε_{py}	0.241	0.684	0.390	0.943	0.428
ψ^*	−0.652	−0.563	−0.392	−0.909	−0.769
R^2 dem	0.944	0.888	0.976	0.890	0.656
R^2 sup	0.982	0.856	0.928	0.833	0.532
Firms	1	4	8	4	4
Cournot	1.000	0.250	0.125	0.333	0.250

Standard errors are calculated using a linear Taylor approximation as in Bärsden (1989) and Steen and Salvanes (1999)

hypothesis for the Northern and Midwest markets, and thus concluded that the Cournot equilibrium is the short-run solution for the Northeast and Midwest markets.

5 Final Comments

The main goals of this paper were to undertake a careful application of NEIO models in the context of a traditional homogeneous oligopoly—specifically in the context of regional cement markets in Brazil. In the process, we intended to address, whenever possible, different concerns that were raised with respect to the NEIO approaches.

Most NEIO critiques are concerned with the estimation procedures, and thus could be addressed in this paper. This is because the estimation procedures for the Brazilian cement regional markets were conducted under a much more favourable scenario due to the availability of the data. Moreover, additional care was taken in terms of considering a structural change test. The evidence indicates that no structural change occurred in any region for the selected period. Furthermore, determining a regionally relevant market and estimating conduct parameters for each region provided better insights than could a single parameter.

A potentially more collusive behavior was expected in regions where fewer firms operate. For the most part, the results are consistent with those expectations. The conduct parameters were higher in the Northern region—where only one firm operates, while in the Southeast region, where the most firms operate, all conduct parameter were indicative of a smaller degree of market power as compared to the other regions. Results are consistent with the presence of market power and are, for the most part, in direct correlation with the number of firms and industrial plants operating in each region. Other interesting findings were derived from the results. In the Northeast and Midwest markets the evidence is consistent with a symmetric Cournot solution.

The available data provided some salient results, as we were able to demonstrate that NEIO models can account for regional market differences. This could provide important information for market regulators.

Possible extensions in terms of similar frameworks relate to at least three research lines: First, researchers should consider an explicitly dynamic theoretical model that would provide sound foundations for the flexible empirical approach considered in this paper. Second, similar developments for the case of differentiated oligopolies would be pertinent, with the work of Nevo (1998) serving as a useful starting point. Finally, researchers could extend their investigations by not only detecting the prevalence of market power, but also identifying its source. In that sense, the association of the conduct parameter with other relevant variables through a latent structure could be relevant to the field of Industrial Economics (see, e.g., McCluskey and Quagrainie 2004).

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Appendix

See Tables 4, 5, 6, 7, and 8.

Table 4 Descriptive statistics

Region	Variable	P	Q	W_1	W_2	W_3	W_4	Y	PZ	Z
Northern	Mean	18.718	119, 773	3.243	17.087	0.461	5.228	3, 141, 532	1, 904	103.79
	Min	14.537	53, 423	2.200	14.423	0.343	2.830	2, 669, 001	1, 468	79.04
	Max	24.887	225, 787	5.300	22.609	0.675	5.658	3, 922, 982	2, 366	133.95
	St-dev	1.453	46, 125	0.296	1.354	0.136	5.536	317, 940	270	32.72
Northeast	Mean	18.066	444, 306	3.662	21.730	0.426	4.274	3, 141, 532	1, 729	100.85
	Min	13.888	217, 465	2.200	14.423	0.343	3.846	2, 669, 001	1, 468	79.04
	Max	24.634	225, 787	4.800	29.054	0.621	5.932	3, 922, 982	2, 382	133.95
	St-dev	1.742	144, 017	0.381	1.743	0.105	5.042	178, 071	226	15.66
Southeast	Mean	18.342	1, 510, 598	5.394	31.953	0.483	3.769	3, 141, 532	1, 732	98.98
	Min	14.382	923, 010	2.200	14.423	0.343	2.638	2, 669, 001	1, 468	79.04
	Max	23.891	225, 787	4.800	22.609	0.621	4.901	3, 922, 982	2, 366	133.95
	St-dev	1.468	309, 137	0.488	2.231	0.105	4.652	198, 736	271	105.76
Southern	Mean	16.368	463, 278	4.265	23.850	0.427	4.444	3, 141, 532	1, 633	96.70
	Min	14.599	311, 814	2.200	14.423	0.343	3.433	2, 669, 001	1, 468	79.04
	Max	23.538	225, 787	4.800	22.609	0.621	5.350	3, 922, 982	2, 366	133.95
	St-dev	1.249	84, 865	0.370	1.484	0.087	6.678	207, 278	212	77.46
Midwest	Mean	17.332	221, 968	3.834	30.624	0.487	3.527	3, 141, 532	1, 655	99.02
	Min	14.398	127, 857	2.200	14.423	0.343	2.899	2, 669, 001	1, 468	79.04
	Max	32.345	225, 787	4.800	22.609	0.621	4.541	3, 922, 982	2, 366	133.95
	St-dev	1.779	47, 178	0.328	2.227	0.102	4.632	178, 111	272	13.40

Table 5 Unit roots test

	Variable	ADF2			ADF3		
		OLS	t-stat	p-value	OLS	t-stat	p-value
Northern	W_1	−0.257	−2.159	0.21	−0.386	−2.440	0.36
	W_2	−0.227	−1.728	0.42	−0.418	−2.141	0.51
	W_3	−0.298	−2.059	0.26	−0.546	−2.641	0.25
	W_4	−0.288	−1.956	0.29	−0.612	−2.464	0.29
	P	−0.120	−1.498	0.53	−0.249	−1.910	0.66
	Q	−0.001	0.115	0.97	−0.238	−2.124	0.52
	Y	−0.099	−1.725	0.40	−0.207	−2.551	0.31
	Z	−0.115	−1.975	0.31	−0.169	−1.933	0.65
Northeast	W_1	−0.326	−1.964	0.29	−0.677	−2.979	0.14
	W_2	−0.190	−1.512	0.51	−0.369	−1.972	0.61
	W_3	−0.235	−1.791	0.40	−0.462	−2.522	0.30
	W_4	−0.165	−1.587	0.34	−0.595	−2.283	0.34
	P	−0.221	−1.653	0.45	−0.609	−3.019	0.14
	Q	−0.087	−1.911	0.34	−0.272	−3.460	0.05
	Y	−0.103	−1.688	0.43	−0.197	−2.392	0.39
	Z	−0.129	−1.892	0.45	−0.179	−1.970	0.50
Southeast	W_1	−0.206	−1.895	0.34	−0.398	−2.797	0.19
	W_2	−0.132	−1.451	0.55	−0.279	−2.244	0.47
	W_3	−0.173	−1.704	0.43	−0.356	−2.460	0.35
	W_4	−0.154	−1.570	0.50	−0.226	−2.189	0.49
	P	−0.161	−1.698	0.42	−0.344	−2.557	0.30
	Q	−0.066	−2.191	0.22	−0.095	−1.719	0.74
	Y	−0.103	−1.843	0.35	−0.202	−2.599	0.28
	Z	−0.192	−1.739	0.35	−0.134	−1.912	0.42
Southern	W_1	−0.190	−2.049	0.27	−0.370	−2.955	0.14
	W_2	−0.145	−1.612	0.46	−0.322	−2.511	0.31
	W_3	−0.308	−2.109	0.23	−0.577	−2.887	0.16
	W_4	−0.278	−1.897	0.30	−0.452	−2.766	0.30
	P	−0.143	−1.823	0.38	−0.287	−2.576	0.28
	Q	−0.165	−1.019	0.95	−0.068	−1.484	0.54
	Y	−0.211	−2.594	0.29	−0.106	−1.850	0.35
	Z	−0.112	−1.990	0.34	−0.126	−2.029	0.39
Midwest	W_1	−0.170	−1.754	0.41	−0.350	−2.594	0.28
	W_2	−0.191	−1.867	0.34	−0.359	−2.570	0.29
	W_3	−0.235	−1.655	0.27	−0.401	−2.138	0.27
	W_4	−0.287	−1.939	0.32	−0.416	−2.632	0.33
	P	−0.252	−1.759	0.39	−0.541	−2.779	0.20
	Q	−0.021	−0.500	0.89	−0.650	−2.820	0.19
	Y	−0.104	−1.695	0.42	−0.196	−2.397	0.39
	Z	−0.199	−1.785	0.38	−0.174	−2.011	0.58

Two tests for unit roots were performed, ADF2 and ADF3. Critical values are 2.89 and 3.40, respectively, and thus all variables are $I(1)$ processes

Table 6 Johansen's cointegration test for the demand and supply relation

r	Northern	Northeast	Southeast	Southern	Midwest	Crit. value 5%
Demand						
0	312.8	134.0	115.9	109.2	131.1	33.3

Table 6 continued

r	Northern	Northeast	Southeast	Southern	Midwest	Crit. value 5%
1	119.0	103.6	91.8	69.8	87.4	27.3
2	48.1	34.0	33.8	36.4	34.8	21.3
3	18.9	18.6	22.6	18.7	11.2	14.6
4	3.6*	7.7*	4.7*	6.3*	6.9*	12.1
Supply relation						
0	174.5	134.5	197.2	134.6	141.8	33.3
1	127.5	113.3	138.0	102.4	135.8	27.3
2	99.8	84.2	61.2	91.3	102.2	21.3
3	41.7	64.8	35.0	35.2	27.0	14.6
4	3.4*	9.4*	6.2*	9.2*	10.4*	12.1

Table 7 Separability test

Northern	Northeast	Southeast	Southern	Midwest	Crit. value 5%
279.54	54.33	90.30	66.55	88.74	9.49

Table 8 Poolability test

Parameter	F stat	p-value
P	1.21	0.001
Z	2.12	0.000
Q	3.54	0.000
Y	1.15	0.013
W_1	4.35	0.000
W_2	6.22	0.000
W_3	3.80	0.000
W_4	4.35	0.000

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