Testing a new approach to estimating interregional output multipliers using input–output data for South Korean regions

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ABSTRACT

Flegg's location quotient (FLQ) is a useful tool in estimating *intra*regional output multipliers. Here we use it as one component in estimating *inter*regional multipliers. Using statistical information criteria, we demonstrate that, for South Korea, the best approach is to combine the FLQ with a simple trade model. Since the interregional trade flows do not seem to depend much on distances or adjacency, a gravity model is not required. We also find that the industry-specific FLQ (SFLQ) yields the best results when regions are analysed separately, whereas the FLQ outperforms the SFLQ once interregional trade flows are considered.

Keywords: interregional multipliers; FLQ; SFLQ; gravity model; information criteria

INTRODUCTION

The multipliers that can be derived from a regional input–output (I-O) table are a valuable tool in regional analysis, yet such tables are rarely available and typically have to be constructed via non-survey methods. These methods include several approaches based on location quotients (LQs). Here Flegg's LQ (FLQ) is a method that often performs well (Bonfiglio & Chelli, 2008; Dávila-Flores, 2015; Flegg & Tohmo, 2013, 2016, 2018a; Flegg et al., 2016; Hermannsson, 2016; Kowalewski, 2015; Lamonica & Chelli, 2017; Morrissey, 2016). However, like other LQ-based methods, the FLQ is designed to estimate *intra*regional intermediate transactions and coefficients. With such techniques, the input coefficients for different regions are estimated independently and *inter*regional coefficients are not estimated explicitly.

The reason why interregional I-O transactions are often neglected is that survey-based data on such transactions are rarely available. This makes it difficult to judge which method of estimation should be employed. A dataset constructed by the Bank of Korea for all 16 South Korean regions in 2005 is one of the few survey-based full interregional I-O tables. This dataset has observations on the volume of all intersectoral transactions, both within and across regions.

The existence of this rich dataset allows us to test some alternative theoretical approaches to estimating intraregional and interregional I-O transactions and input coefficients. Our focus is on an innovative approach proposed by Jahn (2017), in which two methods of estimation, the FLQ and a gravity model, are combined in a consistent way to estimate the intraregional and interregional transactions, respectively. All regions are treated simultaneously. Furthermore, the estimated transactions are constrained to equal the national aggregates for

each pair of sectors.

An important contribution of the present paper is its use of statistical information criteria to determine the best model for estimating output multipliers. Such criteria are relevant when the regionalization methods being compared employ very different numbers of parameters. With the FLQ, for instance, one has a choice between pursuing a simple approach, whereby an unknown parameter δ is held to be invariant across both sectors and regions, and more complex approaches where these assumptions are relaxed. Standard performance criteria cannot reveal whether any reduction in error is sufficient to warrant the inclusion of extra parameters. Information criteria can shed light on this issue and are used here to guide the selection of the best model.

The paper is organized as follows. In the next section, the theoretical background of the FLQ and other LQ-based formulae is briefly recalled and the industry-specific FLQ (SFLQ), proposed by Kowalewski (2015), is introduced. Some key characteristics of the South Korean regions are then identified in the third section. Thereafter, the results of applying the FLQ to data for these regions are presented. The emphasis is on choosing an appropriate model. The fifth section examines how the use of the FLQ can be extended to the interregional dimension. Alternative procedures are evaluated in terms of their ability to estimate interregional output multipliers. The usefulness of employing a gravity model to estimate interregional trade flows is examined. The sixth section attempts to put the various multipliers into context. This is followed by a discussion of the application of the recommended modelling approach and then by a conclusion.

THEORETICAL BACKGROUND: LQ-BASED METHODS

Where regional I-O tables are unavailable, survey-based methods are surely the most reliable way of producing them, yet this would go well beyond the time and funding limits of most research projects. A simple and cheap alternative is to employ LQ-based techniques.

In applying LQs, the national transactions matrix is first transformed into an input coefficient matrix. LQ-based techniques assume that the intraregional input coefficients in any region r, b_{ij}^r, depend on the corresponding national input coefficients, a_{ij}, as follows:

$$b_{ij}^r = \min \left(LQ_{ij}^r \times a_{ij}, a_{ij} \right) \tag{1}$$

Here b_{ij}^r can be interpreted as the amount of input from sector i in region r that is required by

sector j in that region to produce one unit of gross output. The a_{ij} and hence b_{ij}^r exclude foreign inputs. LQ_{ij}^r represents an LQ-based formula, such as the FLQ, the simple LQ (SLQ) or cross-industry LQ (CILQ). Formula (1) entails that, where $LQ_{ij}^r \geq 1$, the intraregional coefficients are equated to the corresponding national coefficients. Otherwise, the b_{ij}^r are adjusted downwards to take account of inputs imported from other regions (Kowalewski, 2015).

The SLQ is defined here as:

$$SLQ_i^r = \frac{Q_i^r / Q^r}{Q_i / Q} \tag{2}$$

where Q_i^r denotes the output of regional sector i, while Q_i is the corresponding national figure. Q^r and Q represent the overall output of region r and the nation. The CILQ is defined as:

$$CILQ_{ij}^r = \frac{SLQ_i^r}{SLQ_j^r} \tag{3}$$

where i and j refer to the supplying and purchasing sectors, respectively. As is customary, where $i = j$, we have set $CILQ_{ij}^r = SLQ_i^r$.

However, empirical research has demonstrated that the SLQ, CILQ and related formulae tend to understate a region's imports from other regions and hence tend to overstate multiplier effects (Flegg & Tohmo, 2013, 2018a; Flegg et al., 2016). The FLQ aims to overcome this shortcoming by taking regional size into account (Flegg et al., 1995). The FLQ is defined here as:

$$FLQ_{ij}^r = CILQ_{ij}^r \times \lambda^r \tag{4}$$

where

$$\lambda^r = [\log_2(1 + Q^r / Q)]^\delta \tag{5}$$

Q^r / Q measures regional size in this equation, while the parameter δ controls its convexity. It is assumed that $0 \leq \delta < 1$. As δ rises, so too does the allowance for imports (from other regions or from abroad). $\delta = 0$ represents a special case where $FLQ_{ij}^r = CILQ_{ij}^r$.[1]

A variant of the FLQ is proposed by Kowalewski (2015), whose industry-specific FLQ is defined as:

$$SFLQ_{ij} \equiv CILQ_{ij} \times [\log_2(1 + E^r / E^n)]^{\delta j} \tag{6}$$

where E^r / E^n is regional size in terms of employment. The innovation here is in permitting δ to vary across industries. The relative performance of the FLQ and SFLQ is examined by Flegg

and Tohmo (2018a). However, as they study only two of the 16 South Korean regions in detail, we build upon their work by carrying out a more general analysis of data for all regions.

It is worth noting, finally, that the FLQ's focus is on the output and employment generated within a specific region. As Flegg and Tohmo (2018a) point out, it should only be used in conjunction with national I-O tables where the inter-industry transactions exclude imports (type B tables). In contrast, where the focus is on the overall supply of commodities, Kronenberg's Cross-Hauling Adjusted Regionalization Method (CHARM) can be employed (Többen and Kronenberg, 2015; Flegg and Tohmo, 2018b). CHARM requires type A tables, those where imports have been incorporated into the national transactions table.

SOUTH KOREAN REGIONS

The key characteristics of South Korean regions are presented in Table 1 and their location is illustrated in Figure 1. Regional size can be measured by a region's share of aggregate national output or employment, yet researchers often use employment data because output figures are not so readily available. However, where there is a choice, as here, using output is preferable because employment shares are affected by variations in regional labour productivity.[2] For instance, Gyeonggi has the highest output, whereas Seoul has the highest employment.

Correlation analysis is a helpful way of exploring the relationship between the variables in Table 1.[3] As anticipated by the FLQ approach, the share of national output is positively associated with the intraregional share of inputs ($r = 0.557$; $p = 0.025$) but negatively associated with the share of inputs from other regions ($r = -0.508$; $p = 0.045$).

A salient feature of Table 1 is the marked interregional variation in the share of foreign inputs in gross output, S_f. Here it is noticeable how the metropolitan city of Ulsan has a share well above average. It also has the lowest share of value added, S_v. Indeed, S_f is strongly negatively correlated ($r = -0.932$; $p = 0.000$) with S_v, yet it is not significantly correlated (at the 5% level) with any other variable. S_v is not significantly correlated with any variable apart from S_f.

Also of interest are differences in the degree of self-sufficiency, as measured by the percentage of inputs bought intraregionally. Seoul is the most self-sufficient region in this sense, as it obtained half of its inputs locally, i.e. $\{0.237/(1 - 0.529)\} \approx 0.50$. The provinces of South Jeolla and Gangwon are also relatively self-sufficient, with intraregional purchases of 43% and 42%, respectively. The other regions all bought under 40% of inputs locally.

CHOOSING A MODEL TO ESTIMATE *INTRA*REGIONAL OUTPUT MULTIPLIERS

In this section, we build upon the earlier work of Flegg and Tohmo (2018a) on South Korean regions. Whereas their primary objective was to find appropriate values for the parameter δ, our focus is on methodology and the choice of model. In particular, we wish to determine which of the following approaches is best:

(i)   Using a single global δ for all sectors and all regions.

(ii)   Using a different δ for each region ($\delta = \delta_r$).

(iii) Using a different δ for each sector ($\delta = \delta_j$).

(iv) Using a different δ for each sector and region ($\delta = \delta_{jr}$).

In implementing these approaches, the estimated type I sectoral output multipliers, the $\widehat{m}_j$, were computed for $0 \leq \delta \leq 0.6$ in steps of 0.01. The delta(s) yielding the set of multipliers with the lowest $\hat{\sigma}^2$ (mean squared error), computed as $\hat{\sigma}^2 = (1/n) \Sigma_j (m_j - \widehat{m}_j)^2$, were then chosen. For the first approach, the average was taken over all multipliers (all sectors and regions). For approaches (ii) and (iii), region- or sector-specific values of $\hat{\sigma}^2$ were used to identify the optimal deltas. The third approach is that advocated by Kowalewski (2015). In the final approach, the δ that gave the minimum $\hat{\sigma}^2$ was selected for each multiplier individually. The assumed 'true' intraregional multipliers, the m_j, were calculated using official data.

Before considering any results, we wish to comment on the conventional approach to choosing among different regionalization methods. Typically, measures such as the mean absolute percentage error (MAPE) or Theil's index of inequality (U), which is based on squared errors, have been used as criteria for determining the best model (Bonfiglio & Chelli, 2008; Flegg & Tohmo, 2013, 2016; Kowalewski, 2015). This approach is intuitive but, from a statistical point of view, it is only valid if models with equal numbers of parameters are being compared. Otherwise, a model with more parameters will generally appear to perform better than any sub-model with fewer parameters, even though reality might follow the simple sub-model. Criteria such as MAPE or U are bound to favour models with more parameters.

An attractive solution is to use more refined criteria such as the Bayesian information criterion (BIC) or Akaike's information criterion (AIC), whereby the number of parameters is penalized in order to avoid the 'overfitting' of models (Burnham & Anderson, 2004).

BIC is calculated here as:

$$BIC = n \times \ln(\hat{\sigma}^2) + \ln(n) \times k \qquad (7)$$

where n is the number of observations, k is the number of parameters and $\hat{\sigma}^2$ is the mean squared error, as defined earlier. BIC and AIC differ in one crucial respect: for $n > 2$, AIC imposes a lesser penalty for additional parameters. It is computed here as:

$$AIC = n \times \ln(\hat{\sigma}^2) + 2k \qquad (8)$$

As k rises, with given n, BIC and AIC increasingly diverge, as BIC imposes a rising penalty for extra parameters. In this instance, given $\hat{\sigma}^2 < 1$, a negative optimal value can be expected, so we should be looking for the most negative BIC or AIC. Employing BIC or AIC instead of MAPE or $\hat{\sigma}^2$ to compare regionalization approaches will typically yield a procedure involving fewer parameters.

Our findings are displayed in Table 2. As expected, the FLQ generates much more accurate results than the SLQ and CILQ. Also, given the differences recorded in Table 1 in the key characteristics of South Korean regions, and in the optimal values of δ_r, it is unsurprising that there should be some potential benefits from permitting δ to vary across regions. These benefits are recognized by three of the four criteria but not by BIC, which indicates that the accuracy gained by allowing this flexibility is outweighed by the need to estimate extra parameters.

A more surprising outcome is that BIC and AIC both confirm that the inclusion of 28 sector-specific parameters is warranted by the consequent greater precision in estimating sectoral multipliers. Nonetheless, they are in conflict as regards procedures (iii) and (iv). If the penalties inherent in the BIC formula are imposed on models with more parameters, (iii) is confirmed as the best, whereas the optimal AIC is achieved for (iv). In other words, AIC is suggesting that each region should have a unique set of sector-specific deltas, whereas BIC is indicating that the δ_j should not vary across regions. One is thus left with a dilemma as to which procedure to adopt.

One approach might be to refer to the theoretical properties of AIC and BIC, yet both are penalized likelihood criteria and the resulting formulae (7) and (8) are very similar. Indeed, despite various subtle theoretical differences, the only practical issue is the size of the penalty, which is bigger for BIC than for AIC. Consequently, analysts who wished to avoid unnecessary complexity might opt for BIC, whereas those most concerned about omitting relevant parameters might prefer AIC. Nonetheless, by employing BIC rather than AIC, one would be lowering the probability of wrongly including irrelevant parameters, yet raising the probability

of wrongly excluding relevant parameters. The converse would be true for AIC.

There is, however, a compelling statistical argument for not accepting the AIC outcome in this instance: $k = n$ for the fourth approach, so any outcome derived therefrom is questionable since we have no degrees of freedom. Furthermore, from a practical perspective, it would be extremely difficult to implement the SFLQ approach if the δ_j varied across regions.

Although AIC and BIC can help to shed light on whether a more complex model is warranted, such criteria only account for the statistical overfitting that might occur. They still assume that the parameters can be estimated from the observations, yet this is not normally possible. As the true multipliers are usually unknown, the δ_j cannot be estimated from the observations. A novel solution to this estimation problem is proposed by Kowalewski (2015).

Kowalewski posits a regression model of the following form:

$$\delta_j = \alpha + \beta_1\,CL_j + \beta_2\,SLQ_j + \beta_3\,IM_j + \beta_4\,VA_j + \varepsilon_j \tag{9}$$

where CL_j is the coefficient of localization, which measures the degree of concentration of national industry j, IM_j is the share of foreign imports in total national intermediate inputs, VA_j is the share of value added in total national output and ε_j is an error term. Regional data are needed for SLQ_j, whereas CL_j, IM_j and VA_j require national data. CL_j is calculated as:

$$CL_j \equiv 0.5 \sum_r \left| \frac{E_j^r}{E_j^n} - \frac{E^r}{E^n} \right| \tag{10}$$

Flegg and Tohmo (2018a) fitted model (9) to data for individual South Korean regions but found that the results exhibited considerable instability. Consequently, they modified this model by imposing the restriction $\beta_2 = 0$ and re-expressing the dependent variable as the mean value of δ_j across all regions. SLQ_j was excluded as it is a region-specific variable.

Using data for 27 sectors and 16 regions, Flegg and Tohmo obtained the following result:

$$\delta_j = 0.669 + 0.269\,CL_j - 0.403\,IM_j - 0.628\,VA_j + e_j \tag{11}$$

where e_j is a residual. Two of the regressors (IM_j and VA_j) were highly statistically significant, whereas CL_j was only marginally so. $R^2 = 0.589$. Using this equation, Flegg and Tohmo found that the SFLQ outperformed the FLQ in Daegu, yet the opposite was true for North Gyeongsang.[4] However, they do not give an outcome for the regions as a whole.

Our calculations using equation (11) gave MAPE = 7.3%, which is noticeably better than the figure of 8.0% given in Table 2 for the FLQ (with $\delta = 0.38$). Thus it appears that, on average, there is a potential gain of about 0.7 percentage points from permitting δ to vary across sectors.

This outcome is surprisingly good for a regression with an $R^2 = 0.589$, and it lends support to the SFLQ as a regionalization technique. Moreover, if it were possible to refine this regression and thereby obtain a better fit, then that would strengthen the argument for using the SFLQ. Even so, Flegg and Tohmo note the difficulty of finding suitable new regressors for which data would be readily available. We should also remember that the regression was fitted to data for South Korea, and that the results pertain to an 'average' region in that country, so one does need to be cautious when employing it in other contexts.

ESTIMATING *INTER*REGIONAL OUTPUT MULTIPLIERS

In this section, we extend the regionalization from the intraregional to the interregional dimension. Our goal is to find good models for the estimation of interregional multipliers. The South Korean I-O table is, in fact, an interregional table since it considers the transactions of every sector in every region with every sector in every other region. It is possible, therefore, to calculate interregional multipliers. We start by examining the distinction between intraregional and interregional multipliers.

The elements of the interregional I-O matrix are defined as z_{ij}^{sr}, denoting the value of transactions from sector i in region s to sector j in region r. The notation follows Jahn (2017) and can be read as $z_{i \to j}^{s \to r}$.

The intraregional multipliers considered previously are derived from the intraregional Leontief inverse matrices $K^r = (I - B^r)^{-1}$, which are, in turn, derived from the intraregional intermediate input coefficient matrices B^r with elements $b_{ij}^r = z_{ij}^{rr}/x_j^r$, where x_j^r denotes the output of sector j in region r. With k_{ij}^r being the elements of the intraregional Leontief inverse, the intraregional multipliers are $N_j^r = \sum_i k_{ij}^r$.

The interregional multipliers are derived analogously from the interregional Leontief inverse matrix $L = (I - A)^{-1}$. The formula includes the interregional input coefficient matrix A, which itself is a block matrix consisting of the input coefficient matrices between all combinations of regions in the following way:

$$A = \begin{pmatrix} A^{11} & \cdots & A^{1R} \\ \vdots & \ddots & \vdots \\ A^{R1} & \cdots & A^{RR} \end{pmatrix} \tag{12}$$

where R denotes the number of regions. The elements of the matrices A^{sr} are the interregional coefficients $a_{ij}^{sr} = z_{ij}^{sr}/x_j^r$. Thus $A^{rr} = B^r$.

It makes sense to define blocks of L similarly to A:

$$L = \begin{pmatrix} L^{11} & \cdots & L^{1R} \\ \vdots & \ddots & \vdots \\ L^{R1} & \cdots & L^{RR} \end{pmatrix} \tag{13}$$

Denoting the elements of L^{sr} as l_{ij}^{sr}, the interregional multipliers are $M_j^r = \sum_{i,s} l_{ij}^{sr}$.

To compute interregional multipliers, intra- and interregional coefficients must be estimated. Jahn (2017) proposes a method whereby the FLQ formula (for the intraregional coefficients) can be combined with different approaches for deriving the interregional coefficients. Unlike the framework in Jahn (2017), however, we do not consider the full I-O table.

Now let $\hat{z}_{ij}^{sr}$ be an estimate of z_{ij}^{sr}. There are two relevant constraints. First, a sector cannot receive more inputs than its known output: $\sum_{i,s} \hat{z}_{ij}^{sr} \leq x_j^r$. Secondly, the estimated interregional transactions should sum to the known national transactions: $\sum_{s,r} \hat{z}_{ij}^{sr} = z_{ij}$.

For the FLQ, estimates of the intraregional coefficients are given by:

$$\hat{a}_{ij}^{rr} = \min(FLQ_{ij}^r * a_{ij}, a_{ij}) \tag{14}$$

We use this way of expressing the FLQ formula to highlight that $\hat{a}_{ij}^{rr} \leq a_{ij}$. Therefore, the 'FLQ residual' (Jahn, 2017) is non-negative:

$$\epsilon_{ij}^{FLQ} = z_{ij} - \sum_r \hat{z}_{ij}^{rr} = z_{ij} - \sum_r x_j^r * \hat{a}_{ij}^{rr} \geq z_{ij} - \sum_r x_j^r * a_{ij} = 0 \tag{15}$$

This means that there is room for interregional transactions, as the estimates of the intraregional transactions sum to a value less than the national transactions (for each sectoral pair).

A simple approach to the estimation of the interregional transactions is to assume that they depend only on the size of the sectors involved in terms of output:

$$\hat{z}_{ij}^{sr} = c * (x_i^s)^{\alpha_1} * \left(x_j^r\right)^{\alpha_2} \quad \text{for } s \neq r \tag{16}$$

A more sophisticated alternative would be a full gravity model (cf. Jahn, 2017):

$$\hat{z}_{ij}^{sr} = c * (d_{sr})^{\beta_1} * \exp(adj_{sr})^{\beta_2} * (x_i^s)^{\beta_3} * \left(x_j^r\right)^{\beta_4} \quad \text{for } s \neq r \tag{17}$$

where d_{sr} denotes the geographical distance between regions and adj_{sr} is a binary variable indicating whether they are neighbours. Of course, extra (or other) variables could be included in the model. The constant will be determined from the FLQ residual such that $\sum_{s,r} \hat{z}_{ij}^{sr} = z_{ij}$ for all pairs $\{i, j\}$. For details, see Jahn (2017).

The final estimates $\bar{z}_{ij}^{sr}$ are obtained by minimizing the objective function:

$$S = \sum_{i,j,s,r} \frac{\left(\bar{z}_{ij}^{sr} - \hat{z}_{ij}^{sr}\right)^2}{\bar{z}_{ij}^{sr}} \tag{18}$$

subject to $\sum_{i,s} \bar{z}_{ij}^{sr} \leq x_j^r$ and $\sum_{s,r} \bar{z}_{ij}^{sr} = z_{ij}$.

However, in the South Korean I-O data, there are negative input values. Therefore, in order to formulate a solvable optimization problem, these values were set to zero and all other input values were scaled such that the sum over all inputs equalled the original output value. Distances were calculated from geographical co-ordinates as 'great circle' distances. This is a common procedure in gravity models (e.g., Fingleton et al., 2015; Jahn, 2017).

Before examining any results, we should offer a rationale for our methodological approach. A key facet of this approach is the use of the FLQ in estimating intraregional trade and a gravity model (or a simplification thereof) in estimating interregional trade.[5] There are several reasons why it is more appropriate to use LQs rather than gravity models when predicting intraregional trade flows. For instance, a gravity model would entail defining the distance of a region to itself, which cannot logically be the usual point-to-point distance. Furthermore, if the gravity model also contained a common-border variable, as in equation (17), it is unclear how a region could be seen as being adjacent to itself.

By contrast, the use of LQs for estimating intraregional trade has a big advantage. It allows the modeller to determine how much of the total intermediate transactions (given in the national IO table) is traded intraregionally, by adding all estimated intraregional transactions. The amount of interregional trade follows as a residual since total intermediate transactions are known from the national I-O table (Jahn, 2017). This aspect is very important for the gravity model (and for other models that include a constant) because the general level of trade is captured in the context-dependent constant. Consequently, gravity models alone are unsuitable for assessing how much of the intermediate trade is interregional; rather, they serve as a device for distributing a given amount of interregional intermediate transactions among the different bilateral flows. Thus, we advocate the use of gravity models only for estimating and forecasting interregional trade.[6]

The results of fitting equation (17) are shown in Table 3, which reveals that all variables are statistically significant. Moreover, their estimated coefficients have expected signs and sensible values. For instance, the coefficient 0.868 indicates that a 1% rise in the output of a given supplying sector, *ceteris paribus*, would raise $\hat{z}_{ij}^{sr}$, the estimated value of transactions from

sector i in region s to sector j in region r, by almost 0.9%. By inserting these coefficients into the gravity equation, one can derive estimates of transaction volumes, which can be transformed into coefficients and, ultimately, into interregional multipliers. Alternative distance measures (road distance: $R^2 = 0.478$; average travel time by road: $R^2 = 0.473$) gave very similar results.

Table 4 shows that the exclusion of the geographical properties of regions does not yield a markedly worse fit. Also, there are only minor changes in the magnitude of the estimated output coefficients. At this stage, we cannot be sure whether this outcome is a general result or, instead, attributable to unique properties of the South Korean economy. However, one might expect distance to have less influence in this interregional trade context than in the usual international trade environment. Unfortunately, to our knowledge, no gravity model has been estimated from survey-based data on interregional trade in intermediates, so this supposition cannot be verified, although we can at least be quite sure that the way in which distance is measured is not a significant factor.

When evaluating different methods of estimating the interregional multipliers, our goal is to answer two questions: (i) is the FLQ formula useful as part of the estimation of these multipliers and (ii) should a gravity model be used in that estimation? Therefore, in Table 5, we compare combinations of intraregional methods (SLQ, CILQ and variants of FLQ) with interregional estimation methods (simple and gravity). Here we are not looking for optimal α and β values (equations 16 and 17) but only for optimal δ values (FLQ formula). The α and β values will always be those displayed in Tables 3 and 4.

Contrary to the findings discussed earlier for intraregional multipliers, where AIC and BIC alike ranked the SFLQ as superior to the region-specific FLQ, Table 5 reveals that the opposite is now true. Indeed, AIC and BIC concur that the region-specific FLQ, in combination with a simple interregional trade model, is the best procedure.

When assessing the outcomes from the various approaches, we can refer to some handy rules of thumb proposed by Kass and Raftery (1995) for interpreting the absolute difference, ΔBIC, between two values of BIC: ΔBIC > 10 would indicate 'very strong' evidence against a model with a less negative BIC; $6 \leq \Delta BIC \leq 10$ would represent 'strong' evidence; $2 \leq \Delta BIC < 6$ would show 'positive' evidence; while ΔBIC < 2 would warrant only a bare mention. To illustrate, let us compare the region-specific FLQ with the SFLQ, assuming a simple trade model. In this instance, ΔBIC = 102, which constitutes compelling evidence against the use of

the SFLQ.

Table 5 suggests that it is unhelpful to employ a gravity model when estimating interregional intermediate transactions. For example, if we compare the results for the simple and gravity models, we get $\Delta \text{BIC} = 49$ for the region-specific FLQ and $\Delta \text{BIC} = 158$ for the SFLQ. This represents 'very strong' evidence against the gravity model. In the light of Tables 3 and 4, these outcomes are not unexpected.

Table 5 also demonstrates that the region-specific FLQ convincingly outperforms both CILQ and SLQ when estimating interregional multipliers. Again assuming a simple trade model, BIC is approximately -1189 for the CILQ but -1241 for the FLQ. Hence $\Delta \text{BIC} = 52$, which constitutes 'very strong' evidence against the CILQ. This finding is reinforced by the contrasting outcomes for AIC. The evidence is even stronger for the SLQ: $\Delta \text{BIC} = 171$, while there is also a big disparity in the values of AIC. Thus we can strongly confirm our previous findings regarding the SLQ and CILQ, obtained in the context of intraregional multipliers.

DISCUSSION OF MULTIPLIERS

Here we attempt to put the various multipliers into context. Table 6 shows the means (over all sectors) of the observed interregional and intraregional type I output multipliers for South Korean regions, along with their ratio (M_j^r / N_j^r). A larger ratio implies a larger relative spillover effect of demand shocks to other regions. The highest average ratios are found in Daejeon, Gwangju and Daegu. This is plausible because these regions are metropolitan cities with a limited area, so they cannot produce many intermediate inputs on their own. Furthermore, they have no access to the sea, which impedes direct imports from abroad through seaports. Consequently, they need to rely largely on supplies from the other regions, thereby yielding high ratios of inter- to intraregional multipliers. More generally, Table 6 reveals that the interregional multipliers are 57% bigger on average than their intraregional counterparts; this disparity indicates that interregional intermediate input relations are very important for this economy.

To illustrate the meaning of the various multipliers, let us examine the results for Daejeon and the province of South Jeolla. These regions are interesting because the former has the lowest mean intraregional multiplier in Table 6, whereas the latter has the second highest. Furthermore, Daejeon has the highest ratio of interregional to intraregional multipliers, while South Jeolla has the lowest. This disparity in the intraregional multipliers can be attributed

primarily to the differing proportions of intermediate inputs sourced intraregionally: Table 1 shows that South Jeolla obtained 28.8% of its inputs internally, compared with only 13.3% for Daejeon.[7]

The mean interregional multiplier of 1.963 for Daejeon indicates that, on average, an exogenous rise (fall) of, say, one million won in the demand for goods or services produced by all sectors in this region would generate a rise (fall) in the aggregate output of the overall economy (all sectors, all regions) of approximately 1.963 million won, *ceteris paribus*. For South Jeolla, the estimated change in overall output would be slightly lower, namely 1.935 million won. Where these two regions differ sharply, however, is in terms of the magnitude of the spill-over effects, which would be substantially greater in Daejeon than in South Jeolla. Even so, taking the results as a whole, it is remarkable how little dispersion there is across regions in the size of the interregional and intraregional multipliers.

An interregional multiplier is calculated from the interregional Leontief inverse as the (column) sum of the output effects in all regions and sectors. It is possible, therefore, to determine from this inverse how much of the overall multiplier effect is realized in any given region. Table 7 illustrates the spatial distribution of the interregional multipliers for Daejeon and South Jeolla, averaged over all sectors in each region. It is noticeable that the intraregional part of the multiplier in South Jeolla (1.332) surpasses that in Daejeon (1.166).[8] This is plausible because Daejeon receives a larger share of its inputs from other regions, whereas South Jeolla is more self-sufficient. Another noteworthy aspect is that Daejeon and South Jeolla create by far their biggest multiplier effects in Gyeonggi and Seoul, which Figure 1 shows are not close to either region. However, they are South Korea's two largest regions (see Table 1) and constitute its economic heart. They supply many other regions with intermediate inputs.

IMPLEMENTING THE NEW APPROACH

The first step in implementing our proposed new procedure for obtaining interregional multipliers would be to use the FLQ formula, preferably in its region-specific form, to derive intraregional input coefficients. Table 1 reveals that the optimal values of δ vary considerably across South Korean regions and this feature must be recognized when applying the FLQ formula. One way of doing so would be to employ the following regression model estimated by Flegg and Tohmo (2018a, table 13):

$$\ln \delta = -1.226 + 0.168 \ln R + 0.325 \ln P + 0.317 \ln F + 0.577 D + e \qquad (19)$$

where R is regional size measured in terms of output and expressed as a percentage; P is the proportion of each region's gross output imported from other regions, averaged over all sectors and divided by the mean for all regions; F is the average proportion of each region's gross output imported from abroad, divided by the mean for all regions; D is a binary variable for Daejeon, which was found to be an outlier; e is a residual. Observations on $\ln \delta$ were derived by finding the value of δ that minimized MAPE for each region. The model comfortably passed all χ^2 diagnostic tests. Moreover, $\ln R$, $\ln F$ and D were highly statistically significant ($p < 0.001$), while $\ln P$ was significant at 5% (two-tailed tests). $R^2 = 0.934$.

In terms of conventional statistical criteria, this regression appears to be well specified. To illustrate its possible use, let us consider two contrasting South Korean regions, Seoul and Ulsan. For Seoul, $R = 18.2$, $P = 0.669$ and $F = 0.514$. Hence Seoul imported 33.1% less than average of its intermediate inputs from other South Korean regions and 48.6% less than average from abroad. The regression gives a predicted $\delta = 0.34$, which is very close to the $\delta = 0.31$ that minimizes MAPE. By contrast, $R = 7.1$, $P = 0.925$ and $F = 2.405$ for Ulsan. While this region purchased only 7.5% less than average of its intermediate inputs from other South Korean regions, it sourced 140.5% more than average from abroad. In this case, the predicted $\delta = 0.525$, which is extremely close to the $\delta = 0.52$ that minimizes MAPE.

More generally, this analysis suggests that, rather than using the same δ for all regions, analysts should consider using a higher value for regions known to use, say, an above-average proportion of either foreign inputs or inputs from other regions. For example, suppose that a region produces 5.5% of national output; furthermore, its use of intermediate inputs from other regions is thought to be 10% above average, whereas its use of foreign inputs is believed to be 20% below average. With $R = 5.5$, $P = 1.1$ and $F = 0.8$, $\delta = 0.354$. By contrast, $P = F = 1$ would yield $\delta = 0.391$.

Nevertheless, as the regression was fitted to South Korean data, one would need to be cautious when employing it elsewhere: the values of δ may vary not just across regions within a given country but also across countries. For instance, while $\delta \approx 0.38$ appears to be the best single value for South Korea, $\delta \approx 0.25$ seems more suitable for Finnish regions (Flegg and Tohmo, 2013). A possible explanation of this phenomenon is that South Korean regions typically import a substantially higher proportion of their inputs from other domestic regions than do Finnish regions. Consequently, to adjust for this disparity in import propensities, a higher value of δ is required in South Korea than in Finland (Flegg and Tohmo, 2018b).

The second step in implementing our proposed new procedure would be to construct a simple interregional trade model to compute the interregional intermediate input volumes.

However, if an analyst were only interested in a single region, it would be possible to simplify the whole procedure by combining the rest of the country's regions into a single 'other' region. The resulting two-region framework would eliminate the need to estimate interregional transactions between regions that were not of interest.

CONCLUSION

Many studies have shown the FLQ formula to be a useful tool in estimating *intra*regional input coefficients and hence sectoral output multipliers, where it typically outperforms simpler formulae. In this paper, we have employed the FLQ as one component in estimating *inter*regional output multipliers. By using statistical information criteria and official survey-based data for 16 South Korean regions, we demonstrated that the best approach was to use the FLQ to estimate intraregional transactions and a simple trade model to estimate interregional transactions. A key finding here was that the interregional intermediate trade flows in South Korea do not appear to depend much on the distances between regions or on their adjacency, so a gravity model is not needed to estimate them.

In implementing the FLQ approach, one needs to choose an appropriate value or values for the unknown parameter δ. Here four possibilities were identified:
(i)   Using a single global δ for all sectors and all regions.
(ii) Using a different δ for each region.
(iii) Using a different δ for each sector.
(iv) Using a different δ for each sector and region.

Normally, in evaluating competing models, analysts employ criteria such as MAPE or $\hat{\sigma}^2$. However, it was argued that the use of such measures is apt to lead to the choice of overly complex models and that more refined criteria such as AIC or BIC should be used instead. This argument was borne out by the fact that, in the interregional analysis, MAPE and $\hat{\sigma}^2$ picked the most complex approach (iv), whereas AIC and BIC chose the much simpler region-specific approach (ii). These formulations differ greatly in terms of the number of unknown parameters that must be estimated: $28 \times 16 = 448$ for (iv) but only 16 for (ii).

Approach (iii) arises from the industry-specific FLQ procedure proposed by Kowalewski (2015). We found that the SFLQ gave the best results when regions were analysed separately,

whereas the FLQ outperformed the SFLQ once interregional intermediate trade flows were incorporated into the analysis.

The importance of recognizing interregional intermediate trade flows was demonstrated by the fact that the intraregional type I output multipliers averaged 1.25 for the 16 regions, compared with 1.96 for the interregional multipliers. This large disparity indicates that interregional intermediate trade flows are very important for the South Korean economy. If data on interregional transactions are unavailable, one should not simply neglect such flows but instead estimate them by methods such as the one described and tested earlier.

In this study, we have extended the use of the FLQ formula from an analysis of single regions to multiple regions, by combining it with trade models that can yield estimates of interregional intermediate transactions. Our analysis suggested that the FLQ is as useful in estimating interregional output multipliers as it is in estimating intraregional multipliers. Simpler approaches, namely the CILQ and SLQ, gave much less satisfactory results. Furthermore, with the aid of regression models, we illustrated how the FLQ and SFLQ could be employed in a practical setting.

NOTES

1. For a more detailed discussion of the FLQ's properties, see, for example, Bonfiglio & Chelli (2008) and Flegg & Webber (1997, 2000). We have chosen not to discuss the augmented FLQ (AFLQ), which takes regional specialization into account but tends to produce similar results to the FLQ (Bonfiglio and Chelli, 2008; Flegg & Webber, 2000; Flegg et al., 2016; Kowalewski, 2015).
2. The output and employment data in Table 1 exhibit a strong linear relationship ($r = 0.921$). However, this aggregate relationship masks much variability at the sectoral level.
3. The correlation analysis mirrors that in Flegg and Tohmo (2018a, p.11).
4. Zhao & Choi (2015) also investigated this topic using data for these two regions; for a critique of their study, see Flegg and Tohmo (2018a).
5. Boero et al. (2017) pursue a very different and much more complex approach, using US county-level data on supply and demand, along with measures of transport costs, to estimate trade flows. Although this interesting new procedure seems to yield reasonably accurate results, the authors note (p. 12) that it is computationally burdensome, especially where the focus is on a single county.
6. For an interesting and ambitious application of gravity models using Scottish data, and a comparison with other approaches, see Riddington et al. (2006). For some comments on this study, see Flegg and Tohmo (2013, pp. 707−708).
7. As expected, the intraregional share of inputs (Table 1) and the intraregional multiplier (Table 6) are strongly correlated ($r = -0.881$). North Gyeongsang is an exception: its intraregional share is close to the mean for all regions, yet it has the highest multiplier.
8. These numbers differ slightly from the corresponding values in Table 6 owing to differences in the method of calculation.

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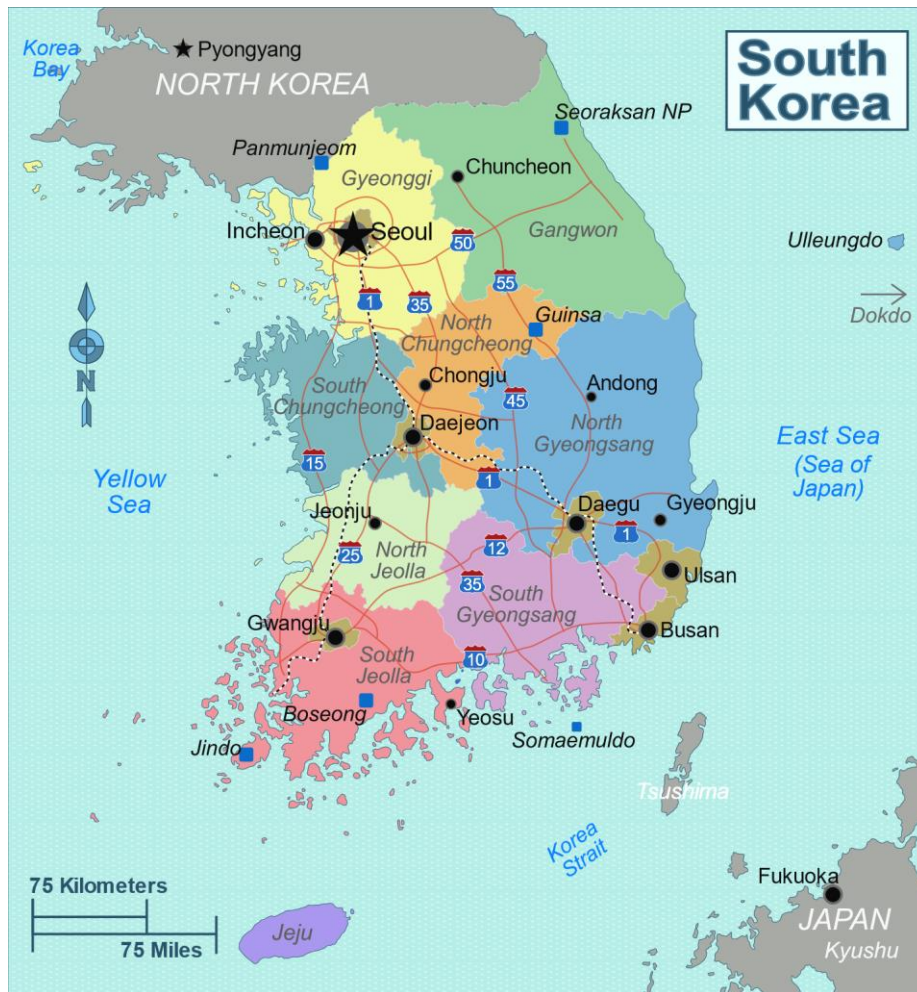
Figure 1. South Korean regions

Source: South Korea location map.svg courtesy of the Perry Castañeda collection; author: Peter Fitzgerald, NordNordWest; licensed under the Creative Commons Attribution-Share Alike 4.0 International; available in Wikimedia Commons.

Table 1. Characteristics of South Korean regions in 2005.

	Region	Share of national output	Share of national employment	Share of inputs from within region	Share of inputs from other regions	Share of inputs from abroad	Share of value added	Optimal value of δ_r
1	Gyeonggi	0.201	0.202	0.226	0.245	0.120	0.410	0.49
2	Seoul	0.182	0.254	0.237	0.173	0.060	0.529	0.31
3	North Gyeongsang	0.084	0.054	0.247	0.254	0.163	0.336	0.39
4	South Gyeongsang	0.073	0.067	0.223	0.284	0.125	0.369	0.36
5	Ulsan	0.071	0.025	0.202	0.240	0.283	0.275	0.52
6	South Jeolla	0.065	0.033	0.288	0.163	0.219	0.331	0.46
7	South Chungcheong	0.063	0.039	0.201	0.274	0.177	0.348	0.45
8	Incheon	0.055	0.048	0.175	0.288	0.171	0.366	0.46
9	Busan	0.051	0.074	0.200	0.266	0.077	0.457	0.31
10	North Chungcheong	0.029	0.030	0.181	0.307	0.104	0.408	0.32
11	Daegu	0.029	0.047	0.189	0.279	0.061	0.472	0.27
12	North Jeolla	0.027	0.032	0.192	0.304	0.074	0.430	0.37
13	Gangwon	0.022	0.029	0.198	0.230	0.044	0.528	0.21
14	Gwangju	0.022	0.028	0.165	0.307	0.099	0.430	0.34
15	Daejeon	0.019	0.027	0.133	0.281	0.065	0.520	0.45
16	Jeju	0.007	0.011	0.172	0.253	0.039	0.536	0.21
Mean		0.0625	0.0625	0.202	0.259	0.118	0.422	0.37
V		0.89	1.08	0.18	0.16	0.58	0.20	0.25

Notes: Shares are expressed as a proportion of gross output. V = coefficient of variation. Seoul is classified as a 'special city'; Busan, Daegu, Daejeon, Gwangju, Incheon and Ulsan as 'metropolitan cities'; Jeju as a 'special self-governing province'; and the rest as 'provinces'.

Source: Adapted from Flegg and Tohmo (2018a, table 9) plus supplementary calculations for δ_r.

Table 2. Performance of different methods in estimating *intra*regional output multipliers.

Method	MAPE	$\hat{\sigma}^2$	BIC	AIC	*k*	*n*
SLQ	22.135	0.1181	−956.9	−956.9	0	448
CILQ	23.045	0.1173	−960.0	−960.0	0	448
FLQ ($\delta = 0.38$)	8.011	0.0175	−1807.5	−1811.6	1	448
FLQ ($\delta = \delta_r$)	7.237	0.0148	−1790.3	−1856.0	16	448
FLQ ($\delta = \delta_j$)	6.371	0.0107	**−1863.5**	−1978.4	28	448
FLQ ($\delta = \delta_{jr}$)	**0.786**	**0.0014**	−196.3	**−2035.2**	448	448

Note: Optimal values are shown in bold.

Table 3. Results for the gravity model (17).

Variable	Coefficient	RSE	t	95% c.i.	
Distance	−0.637	0.015	−41.5	−0.667	−0.607
Adjacency	0.083	0.021	3.9	0.041	0.125
Output: sending sector	0.868	0.003	252.0	0.861	0.875
Output: receiving sector	0.929	0.004	252.4	0.922	0.936
Constant	−18.436	0.116	−159.4	−18.663	−18.210

Notes: $R^2 = 0.475$; $n = 154210$; RSE = robust standard error; c.i. = confidence interval.

Table 4. Results for the simple interregional trade model (16).

Variable	Coefficient	RSE	t	95% c.i.	
Output: sending sector	0.889	0.003	257.7	0.882	0.895
Output: receiving sector	0.950	0.004	266.2	0.943	0.957
Constant	−22.271	0.072	−309.8	−22.412	−22.130

Notes: $R^2 = 0.463$; $n = 154210$.

Table 5. Performance of different methods in estimating interregional output multipliers.

Method	MAPE	$\hat{\sigma}^2$	BIC	AIC	k	n
FLQ (single δ) + gm	9.157	0.0641	−1224.48	−1228.59	1	448
FLQ ($\delta = \delta_j$) + gm	7.873	0.0764	−981.11	−1096.05	28	448
FLQ ($\delta = \delta_r$) + gm	8.147	0.0562	−1191.83	−1257.51	16	448
FLQ ($\delta = \delta_{jr}$) + gm	4.615	**0.0330**	1207.16	−631.79	448	448
FLQ (single δ) + stm	8.574	0.0653	−1216.14	−1220.25	1	448
FLQ ($\delta = \delta_j$) + stm	7.394	0.0537	−1138.78	−1253.71	28	448
FLQ ($\delta = \delta_r$) + stm	7.183	0.0504	**−1240.87**	**−1306.54**	16	448
FLQ ($\delta = \delta_{jr}$) + stm	**4.239**	0.0341	1221.39	−617.56	448	448
CILQ + gm	9.412	0.0673	−1208.72	−1208.72	0	448
CILQ + stm	9.570	0.0703	−1189.31	−1189.31	0	448
SLQ + gm	10.651	0.0961	−1049.19	−1049.19	0	448
SLQ + stm	10.274	0.0919	−1069.63	−1069.63	0	448

Notes: gm = gravity model; stm = simple trade model. Optimal values are shown in bold.

Table 6. Comparison of inter- and intraregional multipliers.

	Interregional		Intraregional		Ratio (inter/intra)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Gyeonggi	1.962	0.335	1.300	0.130	1.504	0.173
Seoul	1.998	0.341	1.274	0.123	1.582	0.313
North Gyeongsang	1.963	0.356	1.306	0.146	1.498	0.178
South Gyeongsang	1.951	0.328	1.282	0.121	1.518	0.189
Ulsan	1.932	0.365	1.249	0.121	1.544	0.244
South Jeolla	1.935	0.361	1.301	0.181	1.490	0.222
South Chungcheong	1.935	0.388	1.243	0.117	1.550	0.245
Incheon	1.915	0.367	1.232	0.099	1.545	0.206
Busan	1.982	0.332	1.277	0.105	1.551	0.219
North Chungcheong	1.993	0.350	1.245	0.115	1.602	0.253
Daegu	2.016	0.340	1.248	0.095	1.619	0.268
North Jeolla	1.961	0.329	1.218	0.103	1.613	0.252
Gangwon	1.961	0.318	1.266	0.134	1.555	0.239
Gwangju	1.986	0.353	1.193	0.079	1.667	0.281
Daejeon	1.963	0.365	1.161	0.066	1.696	0.321
Jeju	1.925	0.360	1.195	0.104	1.614	0.285
Mean	1.961		1.249		1.572	
SD	0.041		0.028		0.055	

Note: SD = standard deviation.

Table 7. Regional decomposition of average interregional multipliers.

	Daejeon	South Jeolla
Gyeonggi	0.129	0.096
Seoul	0.107	0.098
North Gyeongsang	0.065	0.051
South Gyeongsang	0.034	0.044
Ulsan	0.056	0.052
South Jeolla	0.077	1.332
South Chungcheong	0.110	0.047
Incheon	0.048	0.035
Busan	0.022	0.027
North Chungcheong	0.066	0.020
Daegu	0.016	0.014
North Jeolla	0.019	0.049
Gangwon	0.035	0.008
Gwangju	0.009	0.039
Daejeon	1.166	0.011
Jeju	0.003	0.011