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Evaluating the FLQ and AFLQ Formulae for Estimating Regional Input Coefficients: Empirical Evidence for the Province of Córdoba, Argentina

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This paper uses survey-based data for the Argentinian province of Córdoba to conduct an empirical test of the performance of the FLQ and AFLQ formulae for estimating regional input coefficients. A comparison is made with conventional methods based on location quotients. The possibility of using prior information about the extent of self-sufficiency of particular sectors is explored. The empirical work employs a range of statistical criteria with contrasting properties, and examines performance in terms of each method's ability to estimate regional input coefficients, output multipliers and imports. Particular attention is paid to the problem of choosing a value for the unknown parameter δ in the FLQ and AFLQ formulae. These formulae are found to give the best overall results of the non-survey methods considered in the paper. However, the AFLQ typically produces slightly more accurate results than the FLQ, in line with the findings of previous studies.

Keywords: Regional input–output tables; Argentina; Location quotients; FLQ; AFLQ

1 INTRODUCTION

Regional input–output tables are an invaluable aid to regional planning, yet building a survey-based regional table can be complex, expensive and time consuming. As a result, regional tables based primarily on survey data are rare. An exception is the province of Córdoba in Argentina, which is fortunate in having a largely survey-based table for the year 2003 with 124 sectors. Our primary aim is to make full use of this rich data set to assess the relative performance of alternative non-survey methods for constructing regional tables. In doing so, we restrict our attention to methods based on location quotients (LQs).[1]

LQs offer a straightforward and inexpensive way of regionalizing a national input–output table. In the past, analysts have often used the *simple* LQ (SLQ) or the *cross-industry* LQ (CILQ), yet these conventional LQs are known to understate regional trade. This understatement is largely due to the fact that they either rule out (as with the SLQ) or greatly underestimate (as with the CILQ) the extent of *cross-hauling* (the simultaneous importing and exporting of a given commodity).[2]

In an effort to capture the full extent of regional imports from other regions, Flegg et al. (1995) proposed a new variant of the existing LQs, the FLQ formula, which took explicit account of the relative size of a region. They postulated an inverse relationship between a region's relative size and its propensity to import from other regions. Flegg and Webber (1997) subsequently refined this FLQ formula. Another variant, the AFLQ formula, which takes regional specialization into account, was proposed by Flegg and Webber (2000).

The FLQ's focus is on the output and employment generated within a particular region. It should only be applied to national input–output tables where the inter-industry transactions exclude imports (type B tables), such as the one that is examined here (Flegg and Tohmo, 2013b). However, where the focus is on the overall supply of goods, Kronenberg's Cross-Hauling Adjusted Regionalization Method (CHARM) can be employed for purposes of regionalization. This new method is suitable for examining environmental impacts but it can only be used in conjunction with type A tables, those where imports have been incorporated into the national transactions table (Kronenberg, 2009, 2012).

A sizable body of empirical evidence now demonstrates that the FLQ can produce more accurate results than the SLQ and CILQ. This evidence includes, for instance, case studies of Scotland (Flegg and Webber, 2000), Finland (Tohmo, 2004; Flegg and Tohmo, 2013a, 2014) and Germany (Kowalewski, 2015). Furthermore, Bonfiglio and Chelli (2008) carried out a Monte Carlo simulation of 400,000 output multipliers. Here the FLQ clearly outperformed its predecessors in terms of generating the best estimates of these multipliers. Recent applications of the FLQ approach include Lindberg et al. (2012) and Hermannsson (2015).

Even so, the FLQ formula contains an unknown parameter δ and there is much uncertainty as to its appropriate value (Bonfiglio, 2009). This issue is important since the value of δ and regional size jointly determine the size of the adjustment for interregional trade in the FLQ. By exploring this issue, we aim to offer some guidance on what value of δ would be the best to use in particular circumstances.

The rest of the paper is structured as follows. Section 2 outlines how the survey-based input–output table for Córdoba was reconciled with that for Argentina. The data are then used to compare and contrast the regional and national economic structures. In Section 3, we consider why inconsistencies between the regional and national tables might arise, along with the possible implications. Section 4 then explains how alternative estimates of regional input coefficients were derived by adjusting the national coefficients. In Sections 5 and 6, we present our analysis of sectoral input coefficients and output multipliers. This analysis is followed by an investigation into how well the competing methods are able to estimate Córdoba's imports from other Argentinian regions. In Section 8, we pursue greater accuracy by incorporating prior information about the degree of self-sufficiency of particular regional sectors. In Section 9, we discuss alternative ways of determining a value for the unknown parameter δ in the FLQ and AFLQ formulae. Section 10 concludes the paper.

2 INPUT–OUTPUT TABLES FOR CÓRDOBA AND ARGENTINA

The province of Córdoba is located just north of the geographical centre of Argentina. It produces about 8.3% of the gross output of Argentina and employs about 7.9% of its labour force.[3] The provincial capital, Córdoba, which is situated some 700 km north-west of Buenos Aires, is Argentina's second-largest city. The province has a diversified economy and its most important producing industries include agriculture, livestock, motor vehicles and food processing. The principal service industries include wholesale and retail, transportation, real estate and business services. Córdoba has a growing tourism industry. Agriculture is focused upon soy beans, wheat, maize and other cereals. The production of beef and dairy products is very important, and the province also produces products such as fertilizers, agrochemicals, tractors and agricultural machinery. Hydroelectricity and nuclear power are the main source of energy for the province's industries. In addition, many different materials are mined, along with construction materials such as marble and lime.

A 124 × 124 input–output table for the province of Córdoba in 2003 was developed by the Centro de Estudios Bonaerenses (CEB). Extensive surveys of companies in key sectors were used to determine sources of inputs and to measure gross output. These sectors were chosen informally from those with the greatest shares of gross output. The sampling frame was based on the 1994 economic census, which was used to identify the most important firms in each sector. Weights derived from that census were applied to scale the survey data to encompass those companies and sectors not covered in the surveys.[4]

To reconcile the data for individual sectors, sectoral supply and demand were estimated. Many imbalances were evident, which were addressed by replacing the less dependable data with data of superior quality. Figures for supply were provided by the Dirección General de Estadísticas y Censos and the Ministerio de Economía de Córdoba. Demand was estimated via surveys of companies, via the household expenditure survey of the Instituto Nacional de Estadísticas y Censos (INDEC), and by data on exports, also from INDEC. Figures for governmental consumption and household transfers were based on information gathered by the government, by health programmes, by the Administración Nacional de Seguridad Social and by non-profit organizations related to households.

To complete the regional input–output table, survey data on imports of goods and services from the rest of the country and from the rest of the world were added. The CEB carried out a specific survey, in which the questionnaires explicitly asked firms about the regional origin of their inputs and the destination of their sales. Finally, taxes net of subsidies, and trade and freight margins, were incorporated. These latter figures were obtained from the national and provincial tax bodies and from the trade margins survey.

The first problem encountered when trying to reconcile the input–output tables for Córdoba and Argentina was that the most recent national table was for 1997,[5] whereas the provincial table pertained to 2003. Here it was assumed that the national input coefficients had remained stable between 1997 and 2003. This assumption is reviewed in Section 3. Another obstacle was that Córdoba's data were in basic prices, whereas the national data were in producers' prices. Hence the national output data were adjusted to basic prices by deducting taxes on production and adding subsidies, using data from Chisari et al. (2009).

However, the most serious problem encountered was the fact that national output data for 2003 existed for only 30 aggregated sectors. This meant that the LQs required for the regionalization of the national table could only be computed for 30 rather than 124 sectors. To circumvent this problem, the transactions for both Argentina and Córdoba were aggregated into 30 exactly corresponding sectors. This procedure is reviewed in Section 3.

Table 1 near here

There are some noticeable differences in the extent to which Córdoba and Argentina specialize in particular industries. These differences are captured in the simple LQs (SLQs) displayed in Table 1, which were computed using the following formula:[6]

$$SLQ_i \equiv \frac{Q_i^r/\Sigma_i Q_i^r}{Q_i^n/\Sigma_i Q_i^n} \equiv \frac{Q_i^r}{Q_i^n} \times \frac{\Sigma_i Q_i^n}{\Sigma_i Q_i^r}\ , \qquad (1)$$

where Q_i^r is regional output in sector *i* and Q_i^n is the corresponding national figure. $\Sigma_i Q_i^r$ and $\Sigma_i Q_i^n$ are the respective regional and national totals.

Table 1 reveals that Córdoba has a high degree of specialization in sectors 1 and 17. Other sectors exhibiting significant specialization include 4, 13 and 16. It is also worth noting that the key sectors 1, 4 and 17 account for 41% of Córdoba's output. On the other hand, relatively low values of SLQ_i occur in sectors such as 11 and 25. These differences are important since the SLQ approach to regionalization presumes that sectors in which a region is not specialized will be unable to fulfil all of its requirements for a given commodity from within the region and so will need to 'import' some of these items from other regions. Conversely, a region is apt to be self-sufficient in those sectors in which it is specialized.

Table 1 also shows that sectors 2 and 10 play a minuscule role in Córdoba's economy, so we decided to amalgamate sector 2 with 1 and 10 with 3.[7] This decision to base the statistical analysis on 28 rather than 30 sectors has the merit of simplifying the discussion, while ensuring that these two sectors do not have an undue impact on the results.

3 SOME CAVEATS

Before considering any results, we should note some reasons why inconsistencies between the regional and national input–output tables might arise. One concern is that these tables refer to different years and that technological and structural changes in the period 1997–2003 might have altered the national input coefficients significantly. Whilst it is true that there was much macroeconomic instability in Argentina during this period, there is little evidence of major structural change. For instance, there is a very strong correlation (r = 0. 972) between the shares of GDP in 1997 and 2003 of thirteen broadly defined national sectors.[8]

Another possible concern is that the regional table made more use of non-survey data. It was, however, built entirely using national accounting methods and indirect methods were not employed to estimate regional transactions. Moreover, identical sectoral definitions were used in constructing the regional and national tables, based on the ISIC (revision 3). Even so, any differences between Argentina and Córdoba in terms of the mix of commodities in each sector or in the technology employed would still cause problems.

A final caveat concerns possible aggregation bias. Analysts typically face a situation where the national table has many more sectors than the regional table. For example, Flegg and Tohmo (2014) had to aggregate transactions for 58 Finnish national sectors in order to create a table consistent with the data available for 26 regional sectors. To minimize aggregation bias in such cases, Sawyer and Miller (1983), Lahr and Stevens (2002) and other authors emphasize that regionalization of a national table via the use of LQs should precede aggregation.[9] It is also recommended that regional weights should be used when aggregating.

Our study is unusual in that the regional table for 2003 and the initial national table for 1997 had an identical set of 124 sectors. Even so, we could not regionalize the disaggregated national table prior to aggregating it since LQs for 2003 could only be computed for 30 sectors. It should also be noted that we chose not to use regional output weights when aggregating the national table. Our reasoning here was that such data would not normally be available to analysts using LQ-based methods. Indeed, our aim was not to construct the best possible table for Córdoba, since that already existed, but instead to carry out a realistic test of the performance of alternative indirect ways of constructing such a table.

Nevertheless, the loss of information entailed by aggregation must be acknowledged; clearly, it would have been preferable if we had been able to use a disaggregated national table containing 124 sectors. Aggregation bias arises because the detailed sectors comprising each aggregated regional sector are apt to differ in terms of their input requirements and propensity to import from other regions. This bias should be less acute, however, in a diversified regional economy such as Córdoba's (see Table 1).[10]

4 REGIONALIZATION

At the outset, the 28 × 28 national and regional transactions matrices were transformed into matrices of input coefficients. The national coefficient matrix was then 'regionalized' via the following formula:

$$r_{ij} = \beta_{ij} \times a_{ij}, \tag{2}$$

where r_{ij} is the regional input coefficient, β_{ij} is an adjustment coefficient and a_{ij} is the national input coefficient. r_{ij} measures the amount of regional input i needed to produce one unit of regional gross output j; it thus excludes any supplies of i 'imported' from other regions or obtained from abroad. a_{ij} likewise excludes any supplies of i obtained from abroad. The role of β_{ij} is to take account of a region's purchases of input i from other regions.

If we replace β_{ij} in equation (2) with an LQ, we can obtain estimates of the r_{ij}. Thus, for instance:

$$\hat{r}_{ij} = SLQ_i \times a_{ij}. \tag{3}$$

Another possibility is to replace β_{ij} with CILQ$_{ij}$, which is defined as follows:

$$CILQ_{ij} \equiv \frac{SLQ_i}{SLQ_j} \equiv \frac{Q_i^r / Q_i^n}{Q_j^r / Q_j^n}, \tag{4}$$

where the subscripts i and j refer to the supplying and purchasing sectors, respectively. No adjustment is made to the national coefficient where $CILQ_{ij} \geq 1$ and likewise for SLQ_i. The CILQ has the merit that a different scaling can be applied to different cells in a given row of the national coefficient matrix. Unlike the SLQ, the CILQ does not presuppose that a purchasing sector is either an exporter or an importer of a given commodity but never both.

Nonetheless, for reasons alluded to earlier, the authors would recommend the use of the FLQ, which is defined as follows:

$$FLQ_{ij} \equiv CILQ_{ij} \times \lambda^* \quad \text{for } i \neq j, \tag{5}$$

$$FLQ_{ij} \equiv SLQ_i \times \lambda^* \quad \text{for } i = j, \tag{6}$$

where

$$\lambda^* \equiv [\log_2(1 + \Sigma_i Q_i^r / \Sigma_i Q_i^n)]^\delta. \tag{7}$$

It is assumed that $0 \leq \delta < 1$; as δ increases, so too does the allowance for interregional imports. $\delta = 0$ represents a special case whereby $FLQ_{ij} = CILQ_{ij}$ for $i \neq j$ and $FLQ_{ij} = SLQ_i$ for $i = j$. As with other LQ-based formulae, the FLQ is constrained to unity.

Two facets of the FLQ formula are worth stressing: its cross-industry foundations and the explicit role given to regional size. Thus, with the FLQ, the relative size of the regional purchasing and supplying sectors is considered when making an adjustment for interregional trade, as is the relative size of the region. By taking explicit account of a region's relative size, the FLQ should help to address the problem of cross-hauling, which is likely to be more serious in smaller regions than in larger ones (see, for example, Robison and Miller, 1988, table 2). Smaller regions are liable to be more open to interregional trade.

In our empirical analysis, we also consider the *augmented* FLQ (AFLQ) formula formulated by Flegg and Webber (2000), which aims to capture the impact of regional specialization on the size of regional input coefficients. This effect is measured via SLQ_j. The AFLQ is one of the formulae examined in a Monte Carlo study by Bonfiglio and Chelli (2008), who found that it gave marginally more accurate results than the FLQ.[11] It is defined as follows:

$$AFLQ_{ij} \equiv FLQ_{ij} \times \log_2(1 + SLQ_j). \quad (8)$$

However, the specialization term, $\log_2(1 + SLQ_j)$, is only applicable where $SLQ_j > 1$. The AFLQ has the novel property that it can encompass situations where $r_{ij} > a_{ij}$ in equation (2). Like the FLQ, it is constrained to unity.

5 INPUT COEFFICIENTS

Even though analysts are often more concerned with the outcomes for regional sectoral multipliers, it is still fruitful to examine the estimates of the regional input coefficients as well. In line with previous research (Flegg and Tohmo, 2013a, 2014), the following statistics will be employed in this assessment:

$$\text{STPE} = 100\,\Sigma_{ij}\,|\,\hat{r}_{ij} - r_{ij}\,| \,/\, \Sigma_{ij}\, r_{ij}, \quad (9)$$

$$\text{WMAE} = (1/n)\Sigma_j\, w_j\, \Sigma_i\, |\,\hat{r}_{ij} - r_{ij}\,|, \quad (10)$$

$$\tilde{\text{U}}^{\text{S}} = \{\text{sd}(\hat{r}_{ij}) - \text{sd}(r_{ij})\}^2, \quad (11)$$

$$\tilde{\text{U}}^{\text{M}} = \{\text{m}(\hat{r}_{ij}) - \text{m}(r_{ij})\}^2, \quad (12)$$

$$\text{U} = 100\sqrt{\frac{\sum_{ij}(\hat{r}_{ij} - r_{ij})^2}{\sum_{ij} r_{ij}^{\,2}}}, \quad (13)$$

where $\hat{r}_{ij}$ is the estimated regional input coefficient, r_{ij} is the corresponding benchmark value (derived from the survey-based coefficient matrix for Córdoba in 2003) and $n = 28$ is the number of sectors. STPE and WMAE denote the standardized total percentage error and the weighted mean absolute error, respectively. w_j is the proportion of total regional output produced in sector j. $\tilde{\text{U}}^{\text{M}}$ and $\tilde{\text{U}}^{\text{S}}$, where m( ) is the mean and sd( ) is the standard deviation, are components of the mean squared error (MSE); they are included to assess how far each method is able to (i) avoid bias and (ii) replicate the dispersion of the benchmark distribution of coefficients.[12] Finally, U is Theil's well-known index of inequality, which has the merit that it encompasses both bias and variance (Theil et al., 1966, pp. 15–43).

Table 2 near here

A selection of results is shown in Table 2, where the outcomes from the SLQ, CILQ and FLQ will be examined first.[13] The table reveals that the FLQ outperforms the SLQ in terms of all criteria, albeit not very convincingly.[14] This outcome is rather surprising, in view of the more clear-cut findings of Flegg and Tohmo (2013a, 2014) and Kowalewski (2015). The CILQ is the least accurate of the three methods, although it does perform relatively well in terms of the WMAE. Flegg and Tohmo (2014) also found the CILQ to be the least accurate of the four methods they examined using Finnish data.

Table 2 records a somewhat higher optimal δ for U than for the STPE. This divergence can be explained by the different properties built into each formula: by squaring the term $(\hat{r}_{ij} - r_{ij})$ rather than taking an absolute value, U puts more emphasis on avoiding large errors. To achieve this, a larger δ is needed, namely 0.139 rather than 0.118. Another noteworthy finding is that $\tilde{\text{U}}^{\text{M}}$ is minimized when $\delta = 0.087$, whereas U (which takes both bias and dispersion into account) requires δ = 0.139. Thus a strategy of minimizing bias would necessitate using a relatively low value of δ.

Comparing the performance of the FLQ and AFLQ is complicated by the fact that the AFLQ exhibits a higher optimal δ across all criteria. This is no coincidence, as it reflects the different properties of the two formulae.[15] Looking at the results as a whole, it seems reasonable to select δ = 0.1 as a typical value for the FLQ and δ = 0.15 for the AFLQ. On this basis, one can see that the STPE and U judge the AFLQ to be slightly more accurate than the FLQ, whereas the WMAE gives almost identical results for the two methods. $\tilde{U}^M$ and $\tilde{U}^S$ generate conflicting outcomes.

6 OUTPUT MULTIPLIERS

Following previous research (Flegg and Tohmo, 2013a, 2014), the following statistics will be employed to assess the accuracy of the estimated multipliers:

$$\text{MPE} = (100/28)\,\Sigma_j\,(\hat{k}_j - k_j)/k_j, \tag{14}$$

$$\text{STPE} = 100\,\Sigma_j\,|\hat{k}_j - k_j|/\Sigma_j\,k_j, \tag{15}$$

$$\text{WMAE} = \Sigma_j\,w_j\,|\hat{k}_j - k_j|, \tag{16}$$

$$\tilde{U}^M = \{m(\hat{k}_j) - m(k_j)\}^2, \tag{17}$$

$$\tilde{U}^S = \{sd(\hat{k}_j) - sd(k_j)\}^2, \tag{18}$$

$$U = 100\sqrt{\frac{\sum_j(\hat{k}_j - k_j)^2}{\sum_j k_j^2}}, \tag{19}$$

where $\hat{k}_j$ is the estimated type I output multiplier for regional sector j (column sum of the LQ-based Leontief inverse matrix), whereas k_j is the corresponding benchmark value (derived from the survey-based coefficient matrix for Córdoba in 2003). MPE denotes the mean percentage error. This statistic has been added to the set of criteria because it offers a covenient way of measuring the amount of bias in a relative sense.[16] It has also been used in many previous studies. A selection of results is presented in Table 3. As before, the outcomes for the SLQ, CILQ and FLQ will be examined first.

Table 3 near here

We should note at the outset that the errors in the multipliers are much smaller than those in the coefficients. This is an unsurprising outcome: much offsetting of errors occurs when computing multipliers from the Leontief inverse matrix.[17] It may still be possible, therefore, to obtain good estimates of multipliers even if the coefficients are subject to considerable error. Here the choice of an appropriate method of estimation is crucial.

The MPE shows that, on average across the 28 sectors, the FLQ with δ = 0.081 would eliminate any bias in the estimated multipliers, whereas the SLQ and CILQ would overstate the average multiplier by 4.1% and 9.2%, respectively. A potential demerit of the MPE is that large positive and negative errors could offset each other, thereby giving a spurious impression of accuracy. While the STPE, WMAE and U cannot be distorted in this way, they give conflicting rankings of the SLQ and FLQ: the WMAE suggests that the FLQ is the best method, whereas the other two criteria indicate the opposite. However, the differences in the outcomes are small. The CILQ is, once more, shown to be the least effective method.

The results for $\tilde{U}^M$ and $\tilde{U}^S$ in Table 3 display an interesting pattern: as the value of δ rises above 0.05, the FLQ exhibits more bias but a closer correspondence between the standard deviations of $\hat{k}_j$ and k_j. δ = 0.073 is optimal for $\tilde{U}^M$, whereas $\tilde{U}^S$ requires δ = 0.321. U strikes a compromise between these two extremes, indicating a value of 0.104. This value is, however, well above the δ = 0.042 shown by the STPE.

The outcomes for the WMAE in Tables 2 and 3 are very different: whereas δ = 0.008 minimizes the WMAE for coefficients, δ = 0.088 is required for multipliers. Here the impact of dominant sectors such as 1 and 4 can explain much of this difference in outcomes. Another noticeable contrast is that the optimal δ for the STPE is 0.118 for coefficients, yet only 0.042 for multipliers. On the other hand, the outcomes for $\tilde{U}^M$ are fairly similar.

Turning now to an assessment of the relative performance of the FLQ and AFLQ, it again seems appropriate to select 0.1 and 0.15 as the respective typical values of δ for the FLQ and AFLQ. On this basis, one can see that the STPE and U judge the AFLQ to be a little more accurate than the FLQ, whereas the WMAE suggests the opposite. $\tilde{U}^M$ and $\tilde{U}^S$ again give conflicting outcomes.

7 ESTIMATING IMPORTS

A key objective of any LQ-based formula is to estimate a region's imports from other regions and the following statistics will be employed to assess the accuracy of these estimates:

$$\text{MAE} = (1/28)\,\Sigma_j\,|\hat{m}_j - m_j|, \tag{20}$$

$$\text{WMAE} = \Sigma_j\,w_j\,|\hat{m}_j - m_j|, \tag{21}$$

$$\text{TPE} = 100\,(\hat{M} - M)/M\,, \tag{22}$$

where $\hat{m}_j$ is the estimated propensity to import from other regions for sector j in Córdoba (expressed as a proportion of that sector's gross output), whereas m_j is the corresponding benchmark value. MAE and WMAE are the unweighted and weighted mean absolute errors. TPE (total percentage error) measures the error in estimating M, the sum of Córdoba's imports from other regions. A selection of results is shown in Table 4.

Table 4 near here

Looking first at the TPE results, it is striking how the SLQ understates Córdoba's total imports from other regions by 39.5%, while the CILQ understates this sum by 18.2%. An underestimation of regional imports is what we should expect from these conventional LQs. By contrast, the FLQ (with δ = 0.1) overstates total imports by 10.6%, while the AFLQ (with δ = 0.15) does so by 5.0%. Such errors could, in principle at least, be eliminated by using the optimal values of δ shown in Table 4, whereas this would not be possible with the SLQ and CILQ. As regards the SLQ, a decomposition revealed that half of the underestimation was due to the key sector 4, for which m_j = 0.171 but $\hat{m}_j = 0.047$. Sectors 1, 12 and 23 account for much of the remaining error.

Unlike the outcomes for TPE, those for MAD and WMAD exhibit little variation across methods. MAD judges the SLQ to be a bit better than the FLQ, whereas WMAD shows the opposite. The AFLQ performs slightly better than the FLQ in terms of both criteria.

8 AN EXPERIMENT WITH PRIOR INFORMATION

A shortcoming of the assessments of accuracy discussed hitherto is that they do not encompass the possibility of using prior information about the extent of self-sufficiency of particular sectors. For instance, sector 25 has $SLQ_i = 0.527$, yet it is implausible that nearly half of Córdoba's purchases of financial intermediation services should come from other regions. Indeed, many service sectors, such as hotels and restaurants, and also transport, storage and communications, are highly location-specific.

In an effort to improve accuracy, we set $\hat{r}_{ij} = a_{ij}$ for sectors 19–30 in Table 1, on the basis that these sectors predominantly produce non-tradable goods and services, so that no allowance is required for regional imports.[18] The FLQ and AFLQ results followed similar patterns, hence only one set of outcomes is presented in detail in Table 5.

Table 5 near here

By comparing the figures for the SLQ and CILQ in Tables 3 and 5, one can see that the imposition of the constraint $\hat{r}_{ij} = a_{ij}$ on sectors 19–30 typically yields less accurate results. By contrast, the results for the FLQ are markedly improved, although this is only apparent once a much higher value of δ is used. For instance, $\delta = 0.1$ in Table 3 gives U = 10.885, whereas $\delta = 0.4$ in Table 5 gives U = 7.930. There is a comparable enhancement in the outcomes for the AFLQ. As expected, the optimal values of δ are noticeably higher for the AFLQ than for the FLQ. The AFLQ also yields slightly more accurate results than the FLQ; for instance, minima for STPE and U of 6.260 and 7.580, respectively.

The relatively high optimal values of δ shown in Table 5 for the FLQ and AFLQ can easily be explained. Since sectors 19–30 typically exhibit very low propensities to import from other regions, a much lower value of δ is required for them than for the remaining sectors. When these two groups of sectors are combined, as in Table 3, the upshot is a relatively low, but misleading, optimal value of δ.

Table 5 clearly illustrates the merits of not using the same value of δ across all sectors. It is suggested that judicious use should be made of the constraint $\hat{r}_{ij} = a_{ij}$ for sectors where a region is thought to be essentially self-sufficient. For the remaining sectors, Table 5 indicates a δ in the range 0.3 to 0.4 for the FLQ and a somewhat higher value for the AFLQ. It is reassuring that there is a high degree of consistency across the statistical criteria as regards the optimal values of δ.

9 CHOOSING A VALUE FOR δ

The earlier discussion has shown how important it is to select a suitable value for δ, so it is opportune to examine two proposed methods for obtaining such a value for the FLQ. The first method was put forward by Bonfiglio (2009), who derived the following regression equation using simulated data from a Monte Carlo study:

$$\hat{\delta} = 0.994\,PROP - 2.819\,RSRP, \qquad (23)$$

where *PROP* is the propensity to interregional trade (the proportion of a region's total intermediate inputs that is purchased from other regions) and *RSRP* is the relative size of regional purchases (the ratio of total regional to total national intermediate inputs). The principal advantage of a Monte Carlo approach is that the findings should be generally applicable. By contrast, the results derived from a single region may reflect the peculiarities of that region and thus not be valid in general. On the other hand, the simplifying assumptions underlying a Monte Carlo simulation mean that it cannot replicate the detailed economic structure and sectoral interrelationships of regional economies.[19]

To evaluate Bonfiglio's method, two tests were carried out using data for Germany and Finland. In the first application, survey-based data from Kowalewski (2015, table 1), were used to derive the following estimate of δ for the state of Baden-Wuerttemberg in 1993:

$$\hat{\delta} = 0.994 \times 0.205 - 2.819 \times 0.134 = -0.174. \qquad (24)$$

Here the state's share of total German employment (*ibid.*, p. 244) was used as a proxy for *RSRP*. In the second application, using data from Statistics Finland (2000), an even more negative result was obtained for the Finnish province of Uusimaa in 1995:

$$\hat{\delta} = 0.994 \times 0.3016 - 2.819 \times 0.2925 = -0.525. \qquad (25)$$

In this instance, the outcome reflects the fact that Uusimaa is by far the largest Finnish province. It also has the lowest value of *PROP*. For the other nineteen provinces, Bonfiglio's method generated $0 \leq \hat{\delta} < 1$, as required.

These examples serve to highlight a problem with Bonfiglio's approach: the theoretical constraint $\delta \geq 0$ is not imposed on equation (23), so it can yield $\hat{\delta} < 0$ for regions that are relatively large or exhibit below-average propensities to import from other regions or have both characteristics. Cases in point are Uusimaa and Baden-Wuerttemberg. Of course, one could circumvent this problem of negative values by arbitrarily setting $\delta = 0$ but that solution would lack any theoretical basis. Furthermore, for Uusimaa in 1995, setting $\delta = 0$ yields an MPE for the type I output multipliers of 15.0%, whereas using $\delta = 0.383$ yields MPE ≈ 0.[20]

A practical obstacle to the use of Bonfiglio's formula is that data for *PROP* and *RSRP* would not usually be available to analysts, so proxies or assumed values would need to be used. However, this is not really a problem as to *RSRP* since regional size (measured in terms of employment or output) should be a suitable proxy.[21] A more serious issue in any application is apt to be a lack of data for *PROP*.

An alternative method is suggested by Flegg and Tohmo (2013a), who estimated the following regression equation using survey-based data for twenty Finnish regions in 1995:

$$\ln \delta = -1.8379 + 0.33195 \ln R + 1.5834 \ln P - 2.8812 \ln I + \mathrm{e}, \qquad (26)$$

where R is regional size measured in terms of output and expressed as a percentage; P is a survey-based estimate of each region's propensity to import from other regions, divided by the mean value of this propensity for all regions; I is a survey-based estimate of each region's average use of intermediate inputs (including inputs imported from other regions), divided by the corresponding national proportion of intermediate inputs; e is a residual. Observations on $\ln \delta$ were derived by finding the value of δ that minimized the MPE for each Finnish region.

Equation (26) has the merit that $\delta \rightarrow 0$ as $R \rightarrow 0$. Moreover, unlike equation (23), it takes explicit account of any differences between the regional and national ratios of intermediate use. It can, in fact, be rewritten in the following alternative forms, which may be more convenient in some cases (Flegg and Tohmo, 2014):

$$\ln \delta = 0.8169 + 0.33195 \ln R + 1.5834 \ln p - 2.8812 \ln I + e, \qquad (27)$$
$$\ln \delta = -1.8296 + 0.33195 \ln R + 1.5834 \ln p - 2.8812 \ln i + e, \qquad (28)$$

where p is an estimate of each region's propensity to import from other regions, measured as a proportion of gross output, and i is an estimate of each region's average use of intermediate inputs (including inputs imported from other regions).

Using equation (27), along with data from Kowalewski (2015, table 1 and p. 249), the following estimate of δ was derived for Baden-Wuerttemberg in 1993:

$$\hat{\delta} = \exp(0.8169 + 0.33195 \ln 14.38 + 1.5834 \ln 0.1019 - 2.8812 \ln 0.9925) = 0.151.$$

By comparison, Kowalewski (2015, table 3) found an optimal value of $\delta = 0.17$ when using the MPE to evaluate the estimated multipliers.

Two important issues still need to be explored regarding Flegg and Tohmo's approach. The first issue concerns the theoretical foundations of their regression model, while the second pertains to its practical application. As to the first issue, the purpose of the model was to offer a way of refining the choice of a value for δ. The variable P was included to allow for cases where regions had either above-average or below-average propensities to import from other regions, whereas I was included to encompass situations where a region's use of intermediate inputs was either above or below average. $\ln P$ and $\ln I$ should have positive and negative estimated coefficients, respectively, as they do in equation (26).

The role of R is less straightforward, owing to the fact that regional size is an integral part of the FLQ formula, whereby there is a monotonically increasing non-linear relationship between the scalar λ^* and regional size, as shown in equation (7). R was included in the regression to refine this in-built relationship and to reflect the authors' observation that the optimal value of δ tended to rise along with regional size in a sample of twenty Finnish regions (Flegg and Tohmo, 2013a, table 3). Although more research clearly needs to be undertaken to establish whether this same pattern would occur elsewhere, the evidence discussed above for Baden-Wuerttemberg is consistent with the existence of a positive elasticity of δ with respect to R.

As regards the application of Flegg and Tohmo's approach, the way equation (26) is formulated should make it easier for analysts to derive an estimate of δ. In particular, instead of having to come up with a figure for a region's propensity to import from other regions, the analyst would only need to make an informed assumption about how far this propensity diverged from the average for all regions in that country, which should be an easier task. In the same way, an adjustment could be made to allow for any assumed divergence between the regional and national ratios of intermediate use. Furthermore, it would be straightforward (and indeed desirable) to use equation (26) to perform a sensitivity analysis. If the analyst wished to use the AFLQ rather than the FLQ, then a slightly higher value of δ would need to be chosen at the outset.

It is evident that both approaches reviewed here have merits and demerits, which should be borne in mind when deciding which one to pursue. One should also be aware that, with Bonfiglio's method, the estimated δ declines with regional size, whereas Flegg and Tohmo's method exhibits a positive relationship between δ and regional size.

10 CONCLUSION

This paper has used survey-based data for the Argentinian province of Córdoba to assess the performance of the FLQ and AFLQ formulae for estimating regional input coefficients. The empirical work employed a range of statistical criteria with contrasting properties, and examined performance in terms of each method's ability to estimate regional input coefficients, output multipliers and imports.

Our initial findings in terms of coefficients and multipliers showed that the FLQ clearly outperformed the CILQ, yet it performed similarly to the SLQ. However, these initial results did not differentiate between sectors in terms of the perceived extent of self-sufficiency.

When this aspect was considered, the FLQ markedly outperformed both SLQ and CILQ. These conventional LQs also systematically understated aggregate regional imports.

As regards the AFLQ, this formula typically gave slightly more accurate results than the FLQ, so it might be preferred on that basis, along with the fact that it takes regional specialization into account and can encompass situations where regional input coefficients are larger than the corresponding national coefficients.

The FLQ and AFLQ formulae contain a key unknown parameter δ and two possible ways of determining its value were examined, using survey-based data for Finland and Germany. Each approach has both merits and demerits, which should be borne in mind by analysts. More specifically, our results for Córdoba suggested that a δ in the range 0.3 to 0.4 might be appropriate for the FLQ, with 0.4 for the AFLQ. However, for sectors where a region is deemed to be self-sufficient, it is recommended that the national input coefficients should be used, with no allowance made for regional imports.

Nonetheless, as with other pure non-survey methods, the FLQ and AFLQ can only be relied upon to produce a satisfactory initial set of regional input coefficients. An effort should always be made to refine these initial estimates by making use of informed judgement, any available superior data, surveys of key sectors and so on. Indeed, in the authors' opinion, the FLQ and AFLQ are both very well suited to building the non-survey foundations of a hybrid model.[22]

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Notes

1. In particular, we do not explore the commodity-balance approach since it tends to give outcomes similar to those from the simple LQ. RAS is not examined because the detailed regional data it requires are not normally available to analysts.
2. See Flegg and Tohmo (2013a, 2014).
3. Source: Instituto Nacional de Estadísticas y Censos and Ministerio de Economía de la Nación Argentina.
4. The CEB worked with the World Bank and the Ministerio de Economia de Córdoba to construct the survey-based input−output matrix for Córdoba. For a discussion of methodology, see http://estadistica.cba.gov.ar/LinkClick.aspx?fileticket=xEa_WsSZLHo%3D&tabid=413&language=es-AR. Accessed 11 June 2015.
5. Source: Instituto Nacional de Estadísticas y Censos and Ministerio de Economía de la Nación Argentina. Tablas Insumo-Producto para Argentina 1997.
6. All of the LQs used in this paper are based on output rather than on the more usual employment. Sectoral output data are not normally available, so that employment has to be used as a proxy.
7. The unrounded shares of output for sectors 2 and 10 are 0.0000235 and 0.0009098, respectively.
8. GDP was measured in constant prices of 1993. Source: INDEC.
9. Owing to a lack of disaggregated regional data, it is often impossible to compute the LQs needed to regionalize prior to aggregation. This was the situation faced by Flegg and Tohmo (2014).
10. For an excellent treatment of the factors causing aggregation bias, see Lahr and Stevens (2002).
11. For instance, the minimum mean relative absolute distance was 19.1% for the FLQ (with δ = 0.3) but 18.3% for the AFLQ (with δ = 0.4). See Bonfiglio and Chelli (2008, table 1).
12. $\text{MSE} \equiv \{\text{m}(\hat{r}_{ij}) - \text{m}(r_{ij})\}^2 + \{\text{sd}(\hat{r}_{ij}) - \text{sd}(r_{ij})\}^2 + 2(1-\hat{\rho}) \times \text{sd}(\hat{r}_{ij}) \times \text{sd}(r_{ij})$, where $\hat{\rho}$ is the sample correlation coefficient between $\hat{r}_{ij}$ and r_{ij}. Cf. Theil et al., 1966, pp. 29–30.

13. In the tables, the CILQ is calculated with ones along the principal diagonal of the adjustment matrix, whereas the FLQ has SLQ_i along this diagonal. When $\delta = 0$, the FLQ is equivalent to the CILQ with SLQ_i along the diagonal.
14. When sectors 2 and 10 were included as separate sectors, big changes occurred in the outcomes for all statistical criteria except for the WMAE, leading to changes in the ranking of methods. The WMAE still ranked the FLQ as superior to the SLQ, whereas the STPE and U, which do not take the relative size of sectors into account, gave the opposite ranking. To obtain more robust results, we thought it best to exclude these atypical sectors. For multipliers, the same ranking of methods occurred regardless of whether these two sectors were included or not.
15. For a given $SLQ_j > 1$, SLQ_i, δ and regional size, $AFLQ_{ij} > FLQ_{ij}$. Therefore, a larger δ is required to achieve the same adjustment for regional imports as before.
16. A demerit of the MPE, in the context of coefficients, is that it is inflated in cases where r_{ij} is close to zero. Hence results for this measure are not displayed in Table 2.
17. See Miller and Blair (2009, pp. 324‒327) for a numerical example. The detailed results of Sawyer and Miller (1983) provide a very clear illustration of the point that errors in coefficients are likely to be far greater than those in multipliers.
18. In reality, all sectors import to some extent. For instance, an important part of construction is public construction and enterprises awarded contracts for works in Córdoba could be local firms or firms from elsewhere in Argentina. Their inputs could come from Córdoba or from elsewhere. Likewise, inputs for the health sector could be sourced locally or bought from other regions.
19. For instance, Bonfiglio and Chelli (2008, p. 248) generated their regional input and import coefficients randomly in the interval [0, 1], yet that range does not represent a realistic representation of a real regional table, where input coefficients tend to be small, except for those along the principal diagonal.
20. See Flegg and Tohmo (2013a, table 4). The FLQ with $\delta = 0$ is equivalent to the CILQ with the SLQ along the principal diagonal of the adjustment matrix.
21. For example, Bonfiglio (2009, table 5) shows that the Marche region accounted for 2.7% of total Italian employment and 2.6% of intermediate costs in 1974.
22. For more discussion of the hybrid approach, see Jackson (1998) and Lahr (1993, 2001).

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TABLE 1. Sectoral shares of gross output at basic prices in 2003: province of Córdoba and Argentina

Sector	Description	Share for Córdoba	Share for Argentina	SLQ_i
1	Agriculture, cattle raising, hunting and forestry	0.184	0.078	2.364
2	Fishing and related services	0.000	0.003	0.007
3	Primary oil, gas and coal; mining and quarrying	0.005	0.043	0.112
4	Production of food, beverages and tobacco products	0.184	0.122	1.509
5	Manufacture of textile products	0.003	0.013	0.221
6	Tanning, production of leather and leather goods	0.007	0.010	0.760
7	Production of wood and manufacture of wood products	0.003	0.007	0.464
8	Production of paper and paper products	0.006	0.013	0.498
9	Publishing and printing, reproduction of recordings	0.005	0.009	0.522
10	Oil refining	0.001	0.045	0.020
11	Manufacture of substances and chemical products	0.014	0.056	0.248
12	Manufacture of rubber and plastic products	0.014	0.016	0.836
13	Manufacture of non-metallic mineral products	0.010	0.007	1.536
14	Manufacture of common metals	0.008	0.025	0.327
15	Manufacture of metallic products, except for machinery and equipment	0.010	0.010	0.997
16	Manufacture of machinery and equipment, electrical apparatus, technical instruments, and equipment for radio, television and telecommunications	0.031	0.020	1.565
17	Manufacture of vehicles	0.042	0.018	2.321
18	Other industries	0.006	0.004	1.377
19	Electricity, gas and water	0.021	0.021	1.001
20	Construction	0.052	0.040	1.304
21	Wholesale and retail trade	0.078	0.085	0.915
22	Hotels and restaurants	0.021	0.025	0.869
23	Transport, storage and communication services	0.053	0.067	0.797
24	Post and telecommunications	0.022	0.022	0.988
25	Financial intermediation	0.016	0.031	0.527
26	Real estate, business and renting services	0.079	0.077	1.018
27	Public administration and defence	0.030	0.042	0.700
28	Education	0.030	0.025	1.221
29	Health	0.030	0.028	1.052
30	Community, social and personal services	0.036	0.040	0.909

Source: Authors' calculations using data from the Ministerio de Economía de Córdoba.

TABLE 2. Assessment of accuracy: sectoral input coefficients for Córdoba in 2003 (n = 28)

Method	Criterion				
	STPE	WMAE × 10^2	$\tilde{U}^M \times 10^4$	$\tilde{U}^S \times 10^6$	U
SLQ	60.359	0.484	1.162	4.106	56.949
CILQ	73.049	0.452	5.039	67.277	85.995
FLQ (δ = 0)	60.101	0.431	0.727	3.505	56.561
FLQ (δ = 0.05)	59.721	0.434	0.142	1.297	55.560
FLQ (δ = 0.1)	59.353	0.441	0.019	0.141	54.886
FLQ (δ = 0.15)	59.445	0.451	0.431	0.103	54.736
FLQ (δ = 0.2)	60.207	0.469	1.342	1.127	55.131
AFLQ (δ = 0)	61.093	0.459	1.744	4.409	56.962
AFLQ (δ = 0.05)	59.897	0.446	0.655	1.738	55.667
AFLQ (δ = 0.1)	58.875	0.439	0.070	0.289	54.780
AFLQ (δ = 0.15)	58.463	0.439	0.073	0.023	54.474
AFLQ (δ = 0.2)	58.733	0.446	0.632	0.604	54.642
Optimal δ FLQ	0.118	0.008	0.087	0.126	0.139
Optimal δ AFLQ	0.149	0.120	0.125	0.138	0.151

TABLE 3. Assessment of accuracy: sectoral type I output multipliers for Córdoba in 2003 (n = 28)

Method	Criterion					
	MPE	STPE	WMAE	$\tilde{U}^M \times 10^3$	$\tilde{U}^S \times 10^3$	U
SLQ	4.051	8.109	0.118	2.941	2.904	10.709
CILQ	9.182	13.089	0.084	14.680	11.489	18.635
FLQ (δ = 0)	3.145	8.527	0.072	1.553	2.343	11.646
FLQ (δ = 0.05)	1.236	8.349	0.068	0.165	1.827	11.105
FLQ (δ = 0.1)	–0.735	8.502	0.067	0.209	1.413	10.885
FLQ (δ = 0.15)	–2.625	8.883	0.077	1.650	1.105	11.026
FLQ (δ = 0.2)	–4.385	9.600	0.094	4.237	0.779	11.461
AFLQ (δ = 0)	4.922	8.658	0.101	4.226	2.805	11.770
AFLQ (δ = 0.05)	2.850	8.135	0.090	1.303	2.199	10.920
AFLQ (δ = 0.1)	0.729	8.126	0.085	0.044	1.716	10.418
AFLQ (δ = 0.15)	–1.278	8.388	0.084	0.451	1.343	10.333
AFLQ (δ = 0.2)	–3.150	8.850	0.086	2.230	1.048	10.652
Optimal δ FLQ	0.081	0.042	0.088	0.073	0.321	0.104
Optimal δ AFLQ	0.118	0.095	0.136	0.112	0.368	0.137

TABLE 4. Assessment of accuracy: Córdoba's imports from other regions in 2003 (n = 28)

Method	Criterion		
	TPE	MAD	WMAD
SLQ	–39.51	0.0530	0.0519
CILQ	–18.23	0.0904	0.0549
FLQ (δ = 0)	–11.49	0.0601	0.0487
FLQ (δ = 0.05)	–1.05	0.0578	0.0482
FLQ (δ = 0.1)	10.61	0.0571	0.0491
FLQ (δ = 0.15)	22.39	0.0579	0.0518
FLQ (δ = 0.2)	35.13	0.0623	0.0574
AFLQ (δ = 0)	–32.28	0.0552	0.0432
AFLQ (δ = 0.05)	–20.61	0.0518	0.0420
AFLQ (δ = 0.1)	–7.76	0.0496	0.0425
AFLQ (δ = 0.15)	4.98	0.0499	0.0449
AFLQ (δ = 0.2)	17.89	0.0543	0.0491
Optimal δ FLQ	0.055	0.092	0.077
Optimal δ AFLQ	0.130	0.123	0.077

TABLE 5. The impact of using national coefficients for sectors 19–30: sectoral type I output multipliers for Córdoba in 2003 (n = 28)

Method	Criterion					
	MPE	STPE	WMAE	$\tilde{U}^M \times 10^3$	$\tilde{U}^S \times 10^3$	U
SLQ	3.963	12.020	0.190	3.143	13.222	14.085
CILQ	12.487	13.957	0.130	28.350	10.510	19.432
FLQ (δ = 0)	6.756	9.310	0.116	8.253	3.013	12.355
FLQ (δ = 0.05)	5.869	8.644	0.109	6.191	2.480	11.497
FLQ (δ = 0.1)	5.033	8.054	0.102	4.516	2.067	10.746
FLQ (δ = 0.15)	4.256	7.672	0.099	3.195	1.773	10.134
FLQ (δ = 0.2)	3.496	7.431	0.093	2.106	1.355	9.550
FLQ (δ = 0.25)	2.540	6.974	0.077	1.025	0.587	8.857
FLQ (δ = 0.3)	1.558	6.519	0.062	0.310	0.104	8.358
FLQ (δ = 0.35)	0.617	6.594	0.071	0.015	0.008	8.049
FLQ (δ = 0.4)	–0.311	6.736	0.081	0.091	0.208	7.930
FLQ (δ = 0.45)	–1.227	6.837	0.087	0.516	0.560	8.035
Optimal δ FLQ	0.384	0.319	0.306	0.365	0.339	0.402
Optimal δ AFLQ	0.418	0.400	0.400	0.403	0.392	0.440

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1306 **How should economics curricula be evaluated?**
Andrew Mearman

1305 **Temporary employment and wellbeing: Selection or causal?**
Chris Dawson, Don J Webber and Ben Hopkins

1304 **Trade unions and unpaid overtime in Britain**
Michail Veliziotis

1303 **Why do students study economics?**
Andrew Mearman, Aspasia Papa and Don J. Webber

1302 **Estimating regional input coefficients and multipliers: The use of the FLQ is not a gamble**
Anthony T. Flegg and Timo Tohmo