Spatial Interpolation and Disaggregation of Multipliers

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Most non-survey methods of estimating single-region multipliers have been shown to produce a systematic upward bias, unless a considerable amount of ''superior'' data is added. Here it is argued that this conclusion does not need to apply to the case of a non-survey, spatial disaggregation of multipliers. The method proposed consists of four steps with two substantive formulas. The first secures the non-survey interpolation of the lacking intra-regional multipliers for the smaller regions by means of regression. The second secures the non-survey spatial disaggregation of the inter-regional spill-overs by means of second-order distance decays. The method is illustrated numerically by means of the interpolation and disaggregation of the 2 × 14 Type II biregional employment multipliers for aggregate Dutch regions into one 40 × 40 inter-regional employment multiplier matrix for the Netherlands as a whole.

Introduction

The lack of good survey-based input–output tables has been plaguing spatial economics and economic geography for a long time (see Miller and Blair 1985; Richardson 1985). Non-survey, location quotient-type methods of estimating regional multipliers (Schaffer and Chu 1969) have been shown to produce a systematic upward estimation bias because of their implicit or explicit minimizing of inter-regional cross-hauls (Richardson 1972), especially for smaller regions (Willis 1987). This systematic bias can only be neutralized when a considerable amount of ''superior'' data are added (Czamanski and Malizia 1969; Hewings and Jensen 1986). The latter implies that non-survey methods gradually—via hybrid methods—turn into almost full-survey methods, which blurs the distinction and leads to the trivial conclusion that the estimation errors reduce when more ''superior'' data are added (West 1990; Lahr 1993).

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Here we choose to concentrate on directly estimating non-survey multipliers instead of non-survey tables. Estimating non-survey tables has the advantage of being able to also use the accounting identities across rows, although in practice this information is mostly ignored (see Round (1978) and Boomsma and Oosterhaven (1992) for exceptions). Estimating non-survey Type I multipliers has the advantage of not having to also estimate final demand, value added, and foreign imports and exports. We do not, however, advocate estimating non-survey multipliers without any survey data (Katz and Burford 1981), as such an approach leads to unacceptably large errors (Harrigan 1982). Survey-based multipliers are superior, but when the number of regions becomes very large and when more complex demo-economic multipliers (Batey 1985) are involved, the amount of necessary data becomes insurmountable.

This paper argues that the upward bias conclusion for single regions need not apply to the case of a non-survey, spatial disaggregation of multipliers. For, in that case, multiplier accounting identities apply to the columns of the inter-regional multiplier matrix. The usual availability of survey-based multipliers for the larger region or nation prevents systematic estimation errors, as each national multiplier is the weighted average of the nation-to-region multipliers of the smaller constituent subregions. Consequently, their non-survey disaggregation into the region-by-region multiplier matrix does not imply a systematic estimation error, as long as such a disaggregation is made within a consistent inter-regional multiplier scheme (Hewings 1982; Oosterhaven 1984; Sonis and Oosterhaven 1996).[1]

Note that various spatial multiplier decomposition methods, such as those discussed in Sonis, Hewings, and Lee (1994), do not compete with our non-survey disaggregation method, but constitute a supplement. In fact, when survey data are absent, the outcomes of our non-survey disaggregation provide the input for the spatial decomposition of economic structure as well as for the decomposition of structural change (see Rose and Casler 1996; Oosterhaven and Hoen 1998; van der Linden et al. 2000).

The actual need for a spatial disaggregation of regional multipliers arose within a larger research project into the spatial economic effects of new Dutch rail infrastructure (see Elhorst et al. (2000) or Oosterhaven and Elhorst (2003)). Later on, the initial method was generalized to include the spatial disaggregation of full multiplier matrices, and it was generalized to also cover cases with much less regional input–output data available.

The next section discusses the general solution to the spatial disaggregation of full multiplier matrices. It consists of four ''simple'' steps using two substantive formulas. The first secures the non-survey interpolation of lacking intra-regional multiplier matrices by means of a regression on available survey-based intra-regional multiplier matrices. The second secures the non-survey disaggregation of the inter-regional spillovers for the larger regions into the spillovers for the constituting smaller subregions by means of distance decay formulas found in gravity, entropy, and spatial equilibrium models.

The following section illustrates the general method by describing the specific variant that was used for the spatial disaggregation of Type II employment multipliers for incoming migrants, derived from 14 survey-based biregional input–output tables, into one 40 × 40 inter-regional multiplier matrix for the whole of the Netherlands. As opposed to the general method, the illustration only disaggregates multiplier totals and not full multiplier matrices. It thus concentrates on illustrating the spatial dimension of multiplier interpolation and disaggregation, disregarding the sectoral dimension of the general method.

The final section concludes, and discusses the relevance of the Dutch application in different, less input–output data-rich settings.

Spatial multiplier interpolation and disaggregation in general

The general case considers one single large region n, which we will call "nation," and a set of R smaller regions r that constitute the large region n ($r \in n$ and $\sum r = n$). Where appropriate, we will distinguish between regions r' with endogenous impact and regions r with exogenous impulse. Furthermore, we distinguish between a region at hand r and the complement total of all other regions o (thus $r+o=n$). As to industries, we assume that all regions have the same set of I industries, with i indicating industries of impact and j indicating industries to which the exogenous impulse applies. This "same set of industries" assumption implies that some industries may well be non-existent in some regions. Furthermore, without much loss of generality, we assume that whatever data are available at the regional level will be available for all industries alike. With these assumptions on industries, we are able to concentrate on the *spatial* component of the multiplier disaggregation problem, however, without losing the sectoral dimension.

The *most general formulation* of the disaggregation problem is: how to estimate a full inter-regional and inter-industry multiplier matrix, $\mathbf{M}\{m_{ij}^{r'r}\}$, given only one row with the columnwise (nation-to-region) totals of the multiplier matrix, $\mathbf{m}\{m_{\bullet j}^{nr} = \sum_{r'} \sum_i m_{ij}^{r'r}\}$. In this problem statement, the typical cell of $\mathbf{M}$ indicates the impact on industry i in region r' of an exogenous impulse in industry j in region r, and $\bullet$ and n indicate summation over the index concerned.

In practice, in the *typical spatial case*, intra-regional multiplier matrices may be available from comparably constructed input–output models for several regions (m_{ij}^{rr}) as well as for the nation as a whole (m_{ij}^{nn}). In that case, the minimally necessary information specified in the general problem statement is not yet available, as the latter requires that the nation-to-region multiplier totals ($m_{\bullet j}^{nr}$) are given instead of only the column totals of some of the intra-regional blocks of $\mathbf{M}(m_{\bullet j}^{rr})$. Note that these intra-regional totals are less than or equal to the nation-to-region totals by definition (i.e., $m_{\bullet j}^{rr} \leq m_{\bullet j}^{nr}$), but that this does not necessarily imply that $m_{ij}^{rr} \leq m_{ij}^{nn}$, although this is empirically very likely.

In this typical spatial case, this lacking information may be estimated in a number of ways:

1. When absolutely no other data are given, the simplest assumption is that each regional industry will have the same nation-to-region multiplier total as the comparable national industry, that is, $m_{\bullet j}^{nr} = m_{\bullet j}^{nn}$. This assumption is crude but implies no systematic estimation bias, as the correctly weighted sum of the nation-to-region multiplier totals equals the national multiplier total per industry j, that is, $\sum_r w_r m_{\bullet j}^{nr} = m_{\bullet j}^{nn}$, $\forall j$, with $\sum_r w_r = 1$.[2]
2. Normally, however, each regional input–output or social accounting table will contain two import rows or even two full import matrices with regard to, respectively, the total of the other domestic regions and the total of the foreign regions. Differences between the aggregate first-order impacts (i.e., the nation-to-region total input coefficients $a_{\bullet j}^{nr}$) may then be used to differentiate the given national multiplier totals ($m_{\bullet j}^{nn}$). It may, for example, be assumed that the variation in the nation-to-region multiplier totals is (less than) proportional to the variation in the direct nation-to-region impact per industry, that is, $m_{\bullet j}^{nr} = (a_{\bullet j}^{nr}/a_{\bullet j}^{nn})^d m_{\bullet j}^{nn}$, $\forall j$, with $0 < d \leq 1$. Again, this approximation will not lead to a systematic estimation bias, although individual totals may show compensating individual over- and under-estimations as in case 1.
3. In the more ideal case, the available regional input–output or social accounting tables will all have a biregional character, that is, each table will have an intra-regional matrix, an import matrix, an export matrix, and a matrix with the intra-regional transactions within and between the *other* regions of the nation ($o = n - r$). In that case, which is akin to—but also more general than—the illustration in the next section, any biregional input–output or social accounting model will produce the necessary multiplier totals $m_{\bullet j}^{nr}$ directly.

The above three cases also produce the following *additional information*, which is not essential for the general disaggregation method, but which should of course be used to increase its empirical accuracy:

1. full information on some intra-regional submatrices $\mathbf{M}^{rr}\{m_{ij}^{rr}\}$ of the required full multiplier matrix $\mathbf{M}$;
2. as above, plus consistent estimates of the matrices with inter-regional spillovers with regard to the other regions of the nation, either per industry $\mathbf{M}^{or}\{m_{ij}^{or}\}$ or summed over all importing industries $\mathbf{m}^{or}\{m_{\bullet j}^{or}\}$; and
3. as above, but instead of estimates, actual measurements will be available for the regions at hand.

Besides, in practice, all other kinds of non-essential, additional data may be available and should be used to reach the maximal accuracy of the final, disaggregated multiplier matrix $\mathbf{M}$. However, in the description of the general disaggregation procedure below, such additional information will be assumed absent. The numerical illustration in the next section, inter alia, serves to show how such additional information may be incorporated in practical applications of the general procedure.

The endlessness of the possible combinations of additional data complicates the actual multiplier disaggregation problem to such a degree that no theoretical generalization may be reached, unless some commonalities in cases can be found. Without much loss of generality, we state that the multiplier disaggregation process can always best be split up into two main steps:

1. estimation of the block-diagonal, intra-regional parts of the full multiplier matrix when the intra-regional multipliers m_{ij}^{rr} are not available for some or all regions and
2. estimation of the remaining off-block-diagonal, inter-regional parts of the full multiplier matrix, as the split-up of the inter-regional spillovers m_{ij}^{or} over the constituent regions $r' \in o$ will not be available for some or all regions.

The fundamental nature of the difference between these two steps relates to the issue of whether or not the trade-reducing effect of geographical distance and border barriers has already been accounted for.

In a related case, when spatially disaggregating input–output tables instead of multipliers, Oosterhaven (1981, Appendix) introduces a distinction between first-order and second-order distance decays. A *first-order distance decay* applies to the simultaneous estimation of intra-regional transactions and imports or exports from a (technological) total that relates the world as a whole. In that case, no distance decay is accounted for yet, and the total that has to be split up still includes both tradable and non-tradable goods and services. A *second-order distance decay* applies to the further estimation of the shares of different subregions within already estimated imports or exports of a certain region. In that case, the first-order distance decay is already accounted for and non-tradables are already excluded from the estimation. As a consequence, second-order distance decays apply to subtotals, and are fundamentally flatter than the first-order distance decays that apply to the worldwide overall total of inputs or outputs.

The present problem of spatially disaggregating multipliers instead of transactions does not represent an equally sharp distinction between first- and second-order distance decays, but is sufficiently alike to propose a comparable general stepwise solution. These steps include the two main steps and two consistency-assuring additional steps.

Step (1) will consist of *interpolating* the lacking intra-regional multipliers from survey-based intra-regional multipliers that are available for comparable other regions in the same or in different nations. This step is akin to estimating the so-called fundamental economic structure (cf. Jensen, Hewings, and West 1987). To obtain a good explanation of the differences in multiplier sizes, found for different regions, it is advisable to test a series of explanatory variables. One may think of such variables as the geographical size of the region at hand, the smoothness of its borders (length of border/geographical size), its economic size, the size of its largest city indicating its position in the central place hierarchy (*POP1*), and so on:

$$m_{ij}^{rr} = f_{ij}(km_r^2, km\ border_r/km_r^2, GRP_r, POP1_r, \text{etc.}), \quad \forall i \text{ and } j \tag{1}$$

When the sector of impact split-up of the multipliers is not aimed at, (1) may be estimated directly for $m_{\bullet j}^{rr}$, $\forall j$. This first step will thus secure the non-survey estimation of the lacking intra-regional multipliers from a regression on survey-based intra-regional multipliers for comparable regions in the same or in other countries.

Step (2) will simply define the total of the inter-regional spillovers with regard to the other regions as the appropriate residual:

$$m_{ij}^{or} = m_{ij}^{nr} - m_{ij}^{rr} \tag{2}$$

When the sector of impact split-up of the multipliers is not aimed at, (2) may be replaced with $m_{\bullet j}^{or} = m_{\bullet j}^{nr} - m_{\bullet j}^{rr}$.

Step (3) secures the non-survey *disaggregation* of the inter-regional spillovers for the larger region or nation at hand into the spillovers for the smaller units that constitute the larger one. Comparable to the case where a further split-up is made in transaction space, the further split-up in the case of a multiplier disaggregation also needs to take regional demand, regional supply (or production capacity), and interaction barriers (e.g., distance) into consideration. Thus, essentially, an input–output gravity or entropy approach is applied in multiplier space instead of in transaction space, as is usual (cf. Leontief and Strout 1963; Polenske 1970; Wilson 1970; MacGill 1977; Batten 1983). In the demand-driven multiplier case, naturally, the spillover effect to be split up (m_{ij}^{or}) represents regional demand, which leads to the following estimator:

$$\hat{m}_{ij}^{r'r} = m_{ij}^{or}(x_i^{r'}/x_i^{o})D_i^{r'r}, \quad \forall i \text{ and } j \tag{3}$$

In (3), $(x_i^{r'}/x_i^{o})$ represents the share of subregion r' in the total supply of product i from the rest of the nation o, and $D_i^{r'r} \leq 1$ represents the second-order distance decay for sector i with respect to the barriers between regions r' and r. These distance decays may be derived from formulas found in empirical gravity, entropy, or spatial equilibrium models, or may be extrapolated from the first-order distance decays implicit in (1)–(2), as was done in Oosterhaven (1981, Appendix). When the sector of impact split-up of the multipliers is not aimed at, i in (3) may be replaced with $\bullet$. However, in view of the far larger product homogeneity along the rows i as opposed to the columns j of the underlying input–output or social accounting table, this simplification is not desirable.

Step (4) may be redundant if the distance decay estimation in (3) is perfect. When that is not the case, the outcomes of (3) have to be rescaled columnwise to the given or estimated totals from (2):

$$m_{ij}^{r'r} = \hat{m}_{ij}^{r'r}\left(m_{ij}^{or} \Big/ \sum_{r' \in o} \hat{m}_{ij}^{r'r}\right) \tag{4}$$

When the sector of impact split-up of the multipliers is not aimed at, *i* may again be replaced with •.

This finishes the general procedure for the spatial disaggregation of a row with nation-to-region multiplier totals $\mathbf{m}\{m^{nr}_{\bullet j}\}$ into the full inter-regional and inter-industry multiplier matrix $\mathbf{M}\{m^{r'r}_{ij}\}$. The accounting identities (2) and (4) secure the absence of systematic under- or over-estimation as well as the internal consistency of the multiplier matrix. In that sense, the estimation procedure results in *holistically* accurate multipliers (see Jensen 1980). The partitive accuracy of the disaggregation will mainly depend on the empirical quality of the non-survey estimations (1) and (3). Hence, general statements on the *partitive* accuracy of our method cannot be made. The next section, however, will give a first impression.[3]

From 2 × 14 biregional multipliers to 40 × 40 inter-regional multipliers

In this section, the working of the above general disaggregation method is illustrated numerically by means of the disaggregation of a set of Type II regional and national employment multipliers for incoming migrants for 14 aggregate Dutch regions (i.e., 2 × 14 data points) into one 40 × 40 inter-regional employment multiplier matrix for 40 smaller regions comprising the whole of the Netherlands.[4] This last matrix was required as part of a larger investigation into the indirect impacts of various proposals for a new high-speed railway line between Amsterdam airport and the city of Groningen in the north of the Netherlands (see Oosterhaven and Elhorst 2003). The specific multiplier matrix was used to answer the question about the expenditure effects of migration movements that were projected as a consequence of the various proposals.

The example illustrates the proposed general procedure for a *pure spatial multiplier disaggregation*. Hence, it ignores the sectoral dimension as the basic information relates to aggregate biregional multipliers, which are already weighted by the sectoral composition of the migrants' expenditure impulses in each of the 14 aggregate regions, and which are already summed over the impacted sectors in each of the same 14 aggregate regions. For this reason, in this section we can and have to delete the indices for impacted sectors *i*, and the indices of sectors *j* where exogenous impulse occurs.

In fact, for each of the 14 aggregate regions $s \in n$, with $s+o=n$, two survey-based multipliers could be estimated (see the first two columns of Table 1):

1. a Type II intra-regional employment multiplier per migrant household (m^{ss}) and
2. a Type II inter-regional employment spillover into the rest of the country (m^{os}) per migrant household into region *s*.

The only comparable survey-based multipliers can be found in van Dijk and Oosterhaven (1986). Using a Type III single-region input–output model with endogenous unemployment, an endogenous local public sector, and vacancy chains, they estimate an intra-regional multiplier of 430 jobs per 1000 migrating house-

Table 1 Employment Multipliers (Man-Years) Per 1000 Migrating Households Per New Residential Region*

No.	New residential region	Own region (intra-regional)	Rest of country (inter-regional spillovers)	National total
200	Groningen	201	109	310
210	Friesland	197	114	310
220	Drenthe	169	135	304
230	Overijssel	195	110	305
240	Flevoland	144	152	295
250	Gelderland	187	111	298
260	Utrecht	185	113	298
270	Noord-Holland	222	80	302
280	Zuid-Holland	218	80	298
290	Zeeland	193	120	313
300	Noord-Brabant	197	107	304
310	Limburg	200	104	304
271	Greater-Amsterdam	198	99	297
281	Greater-Rotterdam	200	104	304

*See Fig. 1 for the 14 aggregate regions concerned. See the Appendix for the estimation procedure of these crucial 2 × 14 survey-based multipliers.

holds for the total of the three northern provinces for 1975. This is about twice as high as the multipliers for these three provinces separately for 1992/97 (see the first three cells of column 1 in Table 1). There are various reasons to explain this large difference. The three most important are the following: (1) The older multiplier relates to a larger region about 20 years back in time, which must have had a more closed economy and thus larger multipliers, partly because of the continuing globalization. (2) The older multiplier includes the population-size effect on the consumption of local public goods, which is excluded from the present multipliers. (3) The older multiplier relates to the number of jobs whereas the present ones relate to the labor volume in full-time equivalents, which is smaller by definition.

The sum of the above two submultipliers, of course, defines the *required* multiplier total for each aggregate region s: $m^{ns} = m^{ss} + m^{os}$. These totals, however, are only available for the 14 larger regions s, whereas they are required for all 40 subregions r. It is important to note that there are sizeable differences between the submultipliers m^{ss} and m^{os} in the first two columns, whereas the third column of Table 1 with the nation-to-region multipliers m^{ns} differs only little by region.[5] This indicates that the first, possible assumption to generate these lacking totals (see the previous section) already produces a very good estimate. Since no other information is available, the lacking totals for the subregions are estimated using precisely this assumption, but now applied at the lower spatial scale of the aggregate regions s, instead of at the national level, as suggested in the previous section. Thus, it is

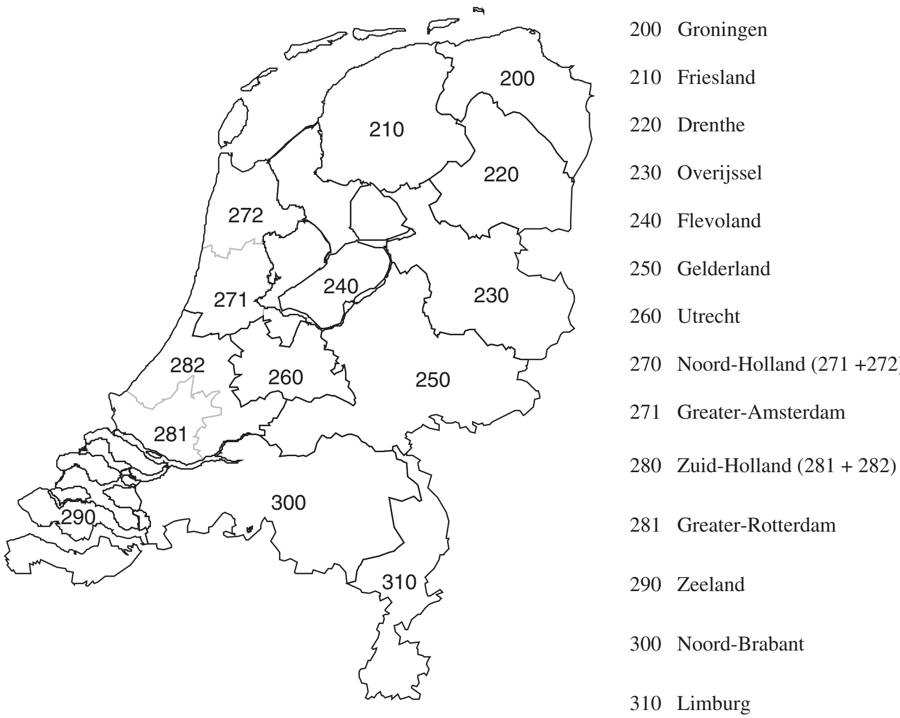

Figure 1. The 14 Dutch regions for which biregional input–output data are available.

assumed that the (nation-to-region) multiplier totals for the 40 subregions *r* are equal to the (nation-to-region) multiplier totals of the 14 larger, aggregate regions *s*, of which they are a part.

Although not strictly necessary for the general method in the previous section, in case of the application an analogous assumption is made for the information available in the first two columns of Table 1. Thus, we *additionally* assume that the values for the submultipliers of the larger 14 regions also apply to the subregions that belong to each of them. As no other information is available, this gives by far the best possible estimate.

To summarize, we make the following three preparatory assumptions, with $o = n - s$:

$$\textit{required} : m^{nr} = m^{ns}, \text{ and } \textit{additionally} : m^{sr} = m^{ss} \text{ and } m^{or} = m^{os}, \quad \forall r \in s \quad (5)$$

After these preparatory assumptions, the four-step spatial disaggregation from the previous section is applied to the specific data estimated and specified in (5).

Step (1). The 40 unknown intra-regional employment multipliers are *spatially interpolated* from the 14 given multipliers in the first column of Table 1. This is done by, first, regressing the share of the intra-regional multiplier in the corresponding national total onto the share of that region in the national economy. The specification is chosen such that it runs through both (0, 0) and (1, 1), as theoretically required, and allows for a non-linear relation:

$$(m^{ss}/m^{ns}) = (GRP^{s}/GRP^{n})^{0.161} \text{ from 14 observations} \tag{6}$$

The above, purely economic explanation of regional multiplier differences is highly significant (T-value of 0.161 = 22.6), but explains less than half of these differences ($R^2 = 0.46$).

Adding geographical variables will of course improve the explanation. For reasons of illustration, three such variables have been tested: spatial centrality (*CEN*), the absolute length of the region's domestic borders (*ADB*), and the relative length of its domestic borders (*RDB*). More centrally located regions are expected to be more oriented toward purchasing from other domestic regions, while regions with long domestic borders either absolute or relative to their own geographical size are also expected to purchase more from other domestic regions.[6]

Adding domestic border length, statistically, proved to be much more valuable than adding spatial centrality. Moreover, adding absolute border length proved to be more valuable than adding border length relative to geographical size, which is not surprising as economic size is already included in (6). Thus, (7) resulted as the best single improvement:

$$(m^{ss}/m^{ns}) = (GRP^{s}/GRP^{n})^{0.131} \exp(-0.00052 ADB^{s}) \tag{7}$$

Both coefficients of this still simple equation are highly significant (T-values are 15.8 and −4.4), while the total explained variance is quite large ($R^2 = 0.80$). Aiming for further improvements would only make sense if more observations are added, for example, of regions in different countries.

In the actual interpolation (Elhorst et al. 2000), (6) was used to estimate the lacking intra-regional multipliers of subregions r from the corresponding multiplier for the larger, aggregate region s:

$$m^{rr} = (GRP^{r}/GRP^{s})^{0.161} m^{ss}, \quad \forall r \in s \tag{8}$$

Step (2). Subtracting (8) from (5) leads to the estimate of the total of the inter-regional spillovers into the other subregions *inside* the same aggregate region, $m^{\underline{s}r}$ ($\underline{s} = s - r$):

$$m^{\underline{s}r} = m^{sr} - m^{rr} \tag{9}$$

Note that the total of the spillovers into subregions *outside* the aggregate region m^{or} ($o = n - s$) is already estimated in (5).

Step (3). Next, these two types of total inter-regional spillovers have to be *spatially disaggregated* into the spillovers into the subregions within and outside the aggregate region s. For this, the distance decay $D^{r'r}$ from a spatial equilibrium model for Europe (Bröcker 1999) is used:

$$D^{r'r} = [\exp(0.00225\ km^{r'r})^{0.582}]^{(1-0.00225)} \tag{10}$$

In (10), $km^{r'r}$ is equal to the distance in kilometers between the points of gravity of subregions r' and r. This distance decay is used for the disaggregation of both types of aggregate inter-regional spillovers.

In (11), this is done for spillovers into subregions *inside* the larger, aggregate region s, that is, to split up $m^{\underline{s}r}$, with $\underline{s} = s - r$:

$$\hat{m}^{r'r} = m^{\underline{s}r}(GRP^{r'}/GRP^{\underline{s}})D^{r'r}, \quad \forall r' \neq r, \text{ and both } r' \text{ and } r \in s \tag{11}$$

In (12) the same is done for spillovers into subregions *outside* the larger, aggregate region s, that is, to split up m^{or}, with $o = n - s$:

$$\hat{m}^{r'r} = m^{or}(GRP^{r'}/GRP^{o})D^{r'r}, \quad \forall r' \in o \text{ and } r \in s \tag{12}$$

Step (4). Finally, to satisfy the multiplier accounting identities, (11) and (12) have to be re-scaled to the appropriate totals from, respectively, (9) and (5):

$$m^{r'r} = \hat{m}^{r'r}\left(\frac{m^{\underline{s}r}}{\sum_{r'\in\underline{s}} m^{r'r}}\right), \quad \forall r' \neq r, \text{ and both } r' \text{ and } r \in s \tag{13}$$

$$m^{r'r} = \hat{m}^{r'r}\left(\frac{m^{or}}{\sum_{r'\in o} m^{r'r}}\right), \quad \forall r' \in o \text{ and } r \in s \tag{14}$$

With (8) and (13)–(14), the disaggregation of the 2×14 Type II biregional employment multipliers for incoming migrants into one 40×40 inter-regional employment multiplier matrix is complete. In Elhorst et al. (2000), this matrix is post-multiplied with the projected numbers of incoming and outgoing migrants (with a negative sign) in each of the 40 regions. The result is an estimate of the changes in regional labor demand that are to be expected as a consequence of the migration effects of the faster rail connections. Although the proposed rail connections only run through 4 of the 14 larger regions (Groningen, Friesland, Flevoland, and greater Amsterdam; see Fig. 1), due to the inter-regional spillovers between all 40 subregions, substantial employment effects are projected for about half of the 40 subregions.

Conclusion

In this article we have shown that the non-survey estimation of an inter-regional multiplier matrix from given column totals does not need to contain a systematic upward estimation bias. Making use of the fundamental distinction between first- and second-order distance decays, the general spatial disaggregation method only needs four "simple" steps using two "substantive" formulas. The first secures the non-survey interpolation of the lacking intra-regional multipliers for the smaller subregions. The second secures the non-survey spatial disaggregation of inter-regional spillovers.

The applicability of the method is illustrated by means of the complex actual disaggregation of 2×14 biregional employment multipliers into one 40×40 inter-regional employment multiplier matrix for the Netherlands as a whole. The application relates to a relatively input–output data-rich statistical context. This, however, does not imply that this approach is restricted to such situations, as is indicated by the less data demanding general procedure summarized above.

Further research into the fundamental economic structure of regions (Jensen, Hewings, and West 1987) may well result in broader statistical explanations of differences in intra-regional multipliers over space and time. These may then be used for a non-biased, non-survey interpolation of intra-regional multipliers, even in countries where regional input–output or social accounting tables are absent. Second, continuing research in the area of spatial equilibrium models (Bröcker 1998; Oosterhaven and Knaap 2003) may well result in more generally supported distance decay functions. These may then be used for the spatial disaggregation of multipliers in countries where such distance decays are not measured empirically. Thus, the general method will become applicable in input–output data-poor environments too.

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Appendix. Derivation of the 2 × 14 biregional employment multipliers

The derivation of the employment multipliers in Table 1 will be described briefly, such that the essential estimation steps, and the nature and quality of the survey-based multipliers to be disaggregated in the main text are clear:

1. The point of departure is the national total average spendable household income for employees earning Dfl. 53,300 for 1995. This year was chosen because the employment, output, and consumption data used below all relate to 1995, which makes an inflation correction redundant. Actually, total consumption per commuter per region of residence would have represented the preferable starting point, but such data are not available.
2. To derive total consumption per household, the national consumption quote of 0.95 is used.
3. To split up the total consumption per 1000 incoming migrant households over the 38 supplying industries in the two relevant regions of origin (own region and the rest of the nation), the regional consumption expenditure columns from the 14 most recent biregional input–output tables for the Netherlands were used. Sectoral technology, expenditure structure, and value totals of these tables all relate to 1992, whereas the inter-regional trade structure relates to 1997 (Eding et al. 1999; RUG/CBS 1999).
4. Steps 1–3 result in 14 exogenous consumption demand columns $\mathbf{f}^{ex}$ (of dimension 2×38) per 1000 incoming migrant households for each of the larger, aggregate regions *s*.

5. In steps 6–8, the standard Type II biregional input–output model $\mathbf{x} = (\mathbf{I} - \mathbf{A} - \mathbf{Q})^{-1}\ \mathbf{f}^{ex}$ (see Oosterhaven 1981, chap. 6) is constructed, and used 14 times to calculate the production effects per 1000 migrant households for each of the 14 larger regions.
6. The 14 $(2 \times 38)^2$ **A**-matrices are directly derived from the biregional input–output tables in RUG/CBS (1999).
7. The 14 $(2 \times 38)^2$ **Q**-matrices are derived in five substeps:
   - Fourteen 2×38 rows with *gross wage/total output* ratios are taken from RUG/CBS (1999).
   - The national average *consumption/gross wage* ratio of 0.62 for wage earners is used.
   - The *independents' labor volume/wage earners' labor volume* ratios for 38 national sectors are multiplied with the national consumption of independents, scaled to the above-derived fourteen 2×38 rows, and added to them. This gives 14 rows with 2×38 *total endogenous consumption/total output* ratios $\{\mathbf{c}^s, \mathbf{c}^o\}$.
   - 14×2 columns with 2×38 consumption package ratios for households in the region at hand ($\mathbf{p}^s$) and for households in the corresponding rest of the nation ($\mathbf{p}^o$) are derived from RUG/CBS (1999).
   - These columns are multiplied with the corresponding part of the above-derived rows to get the 14 biregional $\mathbf{Q} = (\mathbf{c}^s, \mathbf{0})'\ \mathbf{p}^s + (\mathbf{0}, \mathbf{c}^o)'\ \mathbf{p}^o$. The zeros indicate that inter-regional commuting between the 14 regions is assumed to be absent (see further Oosterhaven 1981, chap. 6).
8. Steps 4–7 result in fourteen 2×38 columns with the endogenous production effects ($\mathbf{x}$) per 1000 incoming migrant households per region *s*.
9. Then, fourteen 2×38 rows with *employment/total output* ratios ($\mathbf{e}'$) are derived in two substeps:
   - Fourteen 2×38 *wage earner labor volume/total output* ratios are directly derived from RUG/CBS (1999).
   - Per sector these are raised with the 38 sectoral *national total labor volume/wage earners' labor volume* ratios in order to add the employment of independents per sector per region.
10. Finally, the 14 columns with the endogenous production effects from step 8 are multiplied with the 14 rows with employment ratios from step 9, and aggregated over the 38 sectors per region and the accompanying rest of the country (i.e., $\mathbf{e}^{s\prime}\ \mathbf{x}^s$ and $\mathbf{e}^{o\prime}\ \mathbf{x}^o$). Thus, the first two columns of Table 1 with the employment multipliers per 1000 incoming migrants result.

Notes

1 In essence, such a scheme defines the columnwise disaggregation of the total multiplier for the larger region or nation at hand into the intra-regional multipliers and the inter-regional spillovers for the smaller constituting subregions (see Oosterhaven 1981; Miller and Blair

1985). As the accounting identities only hold for columns of the multiplier matrix, the disaggregation problem cannot be solved by biproportional adaptation, such as RAS (de Mesnard 1994). Besides, a start matrix will almost always be lacking, whereas row totals for the new matrix will be absent almost by definition, which makes biproportional adaptation not possible either.

2 In the case of Type I or Type II input–output models, the correct weights are equal to the exogenous final sales per region that correspond to the multipliers to be added. The correct weights are thus typically very model specific.

3 Note that a full validation of our method would require the availability of a full survey-based multiplier matrix **M**, which may presently only be derived for Japan, Canada, or Finland, but not for the Netherlands.

4 Note that a disaggregation of Type II income multipliers $\mathbf{c}'\,(\mathbf{I}-\mathbf{A}-\mathbf{Q})^{-1}$ runs along precisely the same lines as the present disaggregation of Type II employment multipliers $\mathbf{e}'\,(\mathbf{I}-\mathbf{A}-\mathbf{Q})^{-1}$, as both multipliers are directly tied to Type II production multipliers $\mathbf{i}'\,(\mathbf{I}-\mathbf{A}-\mathbf{Q})^{-1}$ (cf. the Appendix).

5 Among the main causes for these differences are the differences in the foreign import shares for the 14 regions at hand (RUG/CBS 1999). Other reasons include regional differences in labor productivity (see also the Appendix).

6 *CEN* is measured as the distance (km) between the regional and the national center of population gravity. *ADB* is measured as the length of the domestic land border (km), and *RDB* equals *ADB* divided by the land surface (km^2) of the region at hand. Regressing the dependent variable on only these geographical explanatory variables, again without a constant term, produced significant regression coefficients (with *T*-values of -16.0, -7.2, and -7.3), but negative R^2 values (of -0.06, -3.45, and -3.34). This indicates that these three purely geographical explanations, tested without the economic size variable included, all suffer from the ''omitted variables'' problem.

References

Batey, P. W. J. (1985). ''Input–Output Models for Regional Demographic–Economic Analysis: Some Structural Comparisons.'' *Environment and Planning A* 17(1), 77–93.

Batten, D. F. (1983). *Spatial Analysis of Interacting Economies*. Boston: Kluwer-Nijhoff.

Boomsma, P., and J. Oosterhaven. (1992). ''A Double-Entry Method for the Construction of Bi-Regional Input–Output Tables.'' *Journal of Regional Science* 32(3), 269–84.

Bröcker, J. (1998). ''Operational Computable General Equilibrium Modeling.'' *Annals of Regional Science* 32, 367–87.

Bröcker, J. (1999). ''Trans-European Effects of 'Trans-European Networks': A Spatial CGE Analysis.'' *Mimeo*, University of Technology, Dresden.

Czamanski, S., and E. E. Malizia. (1969). ''Applicability and Limitations in the Use of National Input–Output Tables for Regional Studies.'' *Papers of the Regional Science Association* 23, 65–77.

van Dijk, J., and J. Oosterhaven. (1986). ''Regional Impacts of Migrants' Expenditures: An Input–Output/Vacancy-Chain Approach.'' In *Integrated Analysis of Regional Systems. London Papers in Regional Science 15*, 122–47, edited by P. W. J. Batey and M. Madden. London: Pion.

Eding, G. J., J. Oosterhaven, B. de Vet, and H. Nijmeijer. (1999). ''Constructing Regional Supply and Use Tables: Dutch Experiences.'' In *Understanding and Interpreting*

Economic Structure, 237–63, edited by G. D. J. Hewings, M. Sonis, M. Madden, and Y. Kimura. Berlin: Springer-Verlag.

Elhorst, J. P., T. Knaap, J. Oosterhaven, W. E. Romp, T. M. Stelder, and E. Gerritsen. (2000). ''Ruimtelijk Economische Effecten van Zes Zuiderzeelijn Varianten.'' *REG-Publication 22*, University of Groningen.

Harrigan, F. J. (1982). ''The Estimation of Input–Output Multipliers When No Input–Output Model Exists: A Comment.'' *Journal of Regional Science* 22(3), 375–81.

Hewings, G. J. D. (1982). ''Regional and Inter-regional Interdependencies: Alternative Accounting Systems.'' *Environment and Planning A* 14, 1587–1600.

Hewings, G. J. D., and R. C. Jensen. (1986). ''Regional, Inter-regional and Multiregional Input–Output Analysis.'' In *Handbook of Regional and Urban Economics, Volume 1, Regional Economics*, edited by P. Nijkamp. Amsterdam: North-Holland (Chap. 8).

Jensen, R. C. (1980). ''The Concept of Accuracy in Regional Input–Output Models.'' *International Regional Science Review* 5(2), 139–54.

Jensen, R. C., G. J. D. Hewings, and G. R. West. (1987). ''On a Taxonomy of Economies.'' *Australian Journal of Regional Studies* 2(1), 3–24.

Katz, J. L., and R. L. Burford. (1981). ''A Method of Estimation of Input–Output Multipliers When No Input–Output Model Exists.'' *Journal of Regional Science* 21, 151–61.

Lahr, M. (1993). ''A Review of the Literature Supporting the Hybrid Approach to Constructing Regional Input–Output Models.'' *Economic Systems Research* 5(3), 277–94.

Leontief, W. W., and A. Strout. (1963). ''Multiregional Input–Output Analysis.'' In *Structural Interdependence and Economic Development*, 119–49, edited by T. Barna. London: Macmillan.

van der Linden, J. A., J. Oosterhaven, F. A. Cuello, G. J. D. Hewings, and M. Sonis. (2000). ''Fields of Influence of Productivity Change in EC Intercountry Input–Output Tables, 1970–80.'' *Environment & Planning A* 32(7), 1287–1305.

MacGill, S. M. (1977). ''The Lowry Model as an Input–Output Model and its Extension to Incorporate Full Intersectoral Relations.'' *Regional Studies* 11, 337–54.

de Mesnard, L. (1994). ''Unicity of Biproportion.'' *SIAM Journal of Matrix Analysis Application* 15(2), 490–95.

Miller, R. E., and P. D. Blair. (1985). *Input–Output Analysis: Foundations and Extensions*. Englewood Cliffs, NJ: Prentice-Hall.

Oosterhaven, J. (1981). *Inter-regional Input–Output Analysis and Dutch Regional Policy Problems*. Aldershot, UK: Gower.

Oosterhaven, J. (1984). ''A Family of Square and Rectangular Inter-regional Input–Output Tables and Models.'' *Regional Science and Urban Economics* 14, 565–82.

Oosterhaven, J., and J. P. Elhorst. (2003). ''Indirect Economic Benefits of Transport Infrastructure Investments.'' In *Across the Border. Building upon a Quarter Century of Transport Research in the Benelux*, 143–62, edited by W. Dullaert, B. A. M. Jourquin, and J. B. Polak. Antwerp: De Boeck.

Oosterhaven, J., and A. R. Hoen. (1998). ''Preferences, Technology, Trade and Real Income Changes in the European Union: An Intercountry Decomposition Analysis for 1975–1985.'' *Annals of Regional Science* 32(4), 505–24.

Oosterhaven, J., and T. Knaap. (2003). ''Spatial Economic Impacts of Transport Infrastructure Investments.'' In *Transport Projects, Programmes and Policies: Evaluation Needs* *and Capabilities*, 87–105, edited by A. Pearman, P. Mackie, J. Nellthorp, and L. Giorgi. Aldershot: Ashgate.

Polenske, K. R. (1970). ''Empirical Implementation of a Multiregional Input–Output Gravity Trade Model.'' In *Contributions to Input–Output Analysis, Volume I*, 143–63, edited by A. Carter and A. Brody. Amsterdam: North-Holland.

Richardson, H. W. (1972). *Input–Output and Regional Economics*. London: Wiedenfeld & Nicolson.

Richardson, H. W. (1985). ''Input–Output and Economic Base Multipliers: Looking Backward and Forward.'' *Journal of Regional Science* 25(4), 607–662.

Rose, A., and S. Casler. (1996). ''Input–Output Structural Decomposition Analysis: A Critical Appraisal.'' *Economic Systems Research* 8(1), 33–62.

Round, J. I. (1978). ''On Estimating Trade Flows in Inter-Regional Input–Output Models.'' *Regional Science and Urban Economics* 8, 289–302.

RUG/CBS. (1999). ''Regionale Samenhang in Nederland. Bi-regionale input–output tabellen en aanbod- en gebruiktabellen voor de 12 provincies en de twee mainport regio's.'' *RUG/CBS, REG-Publication 20*, University of Groningen.

Schaffer, W. A., and K. Chu. (1969). ''Non-Survey Techniques for Constructing Regional Inter-Industry Models.'' *Papers of the Regional Science Association* 23, 83–101.

Sonis, M., G. J. D. Hewings, and J. K. Lee. (1994). ''Interpreting Spatial Economic Structure and Spatial Multipliers: Three Perspectives.'' *Geographical Analysis* 26(2), 124–51.

Sonis, M., and J. Oosterhaven. (1996). ''Input–Output Cross Analysis: A Theoretical Account.'' *Environment and Planning A* 28, 1507–17.

West, G. R. (1990). ''Regional Trade Estimation: A Hybrid Approach.'' *International Regional Science Review* 13, 103–18.

Willis, K. G. (1987). ''Spatially Disaggregated Input–Output Tables: An Evaluation and Comparison of Survey and Non-Survey Results.'' *Environment and Planning A* 19, 107–16.

Wilson, A. G. (1970). *Entropy in Urban and Regional Modelling*. London: Pion.