PART III

METHODS AND APPROACHES OF INTERREGIONAL ANALYSIS

18 Interregional input–output modeling: spillover effects, feedback loops and intra-industry trade

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1. INTRODUCTION

The resurgence of interest in the spatial location and organization of economic activity generated by the development of new economic geography has once again directed attention to the way in which the regions of a national economy interact. Over the last three decades, production systems have become more fragmented, with different phases in the production system often allocated to different locations in space. As a result, interregional and international trade flows have been growing at rates in excess of the corresponding rates of growth of gross regional or national domestic product.

This process has been propelled in part by a significant spatial reorganization of value chains over the past two or three decades, and the concomitant logistical issues associated with the most efficient coordination of production systems has generated a complex system of interdependent flows, linking regions in one country with regions in another. This process of hollowing out (namely, the substitution of external sources of inputs and sales for intraregional transactions) has seen intra-economy multipliers decreasing while interregional spillovers are increasing; this phenomenon is occurring at the interregional and at the international scale.

For many decades, development agencies paid little attention to the intra-national dimensions of economic development. It was assumed that a similar project would generate the same spatial and total impact wherever it was located within the nation at hand. The development of multiregional input–output and computable general equilibrium models has revealed that, contrary to Friedman (2005), the world *inside* nations is not flat. Space is spiky and it is uneven. Projects generate different spatial distributive impacts depending on the nature (highway, new business, investment in human capital) and on the location of the project. Further, spillover effects are not necessarily symmetric: a project in Hokkaido may generate larger impacts on Kanto than a project in Kanto generates on Hokkaido. In addition, projects may disturb the spatial equilibrium, as factors such as capital and labor respond to changes in opportunities and rents by relocating.

As the processes of fragmentation and hollowing out continue, interregional dependency will assume even greater importance in explaining the growth and development paths of economies. The tragic events in 2011 in Fukushima, Japan (earthquake and tsunami) and in Thailand (floods) revealed risks associated with extensive supply chains that reach across many widely spread locations, and showed that disruptions in even the smallest components may generate severe stress on the whole productive system.

Regional economies are becoming both more competitive and more integrated at the same time, creating new challenges for policy analysts. To understand the new challenges to economic development, it is essential to develop and maintain tools – such an interregional input–output models – that can assist in tracking these changes. As in almost all formal economic modeling, the distinction between endogenous and exogenous is very important; in constructing single-region models, it is often assumed that the impacts of exogenous change are of a top–down nature with no feedback effects. However, the changing structure of regional economies has resulted in greater role for interregional trade and the possibility that feedbacks could prove to be important.

This chapter will focus on ways in which the modeling of flows of goods and services can be handled, and how the outcomes of such models are different across countries and along the spatial hierarchy. To this end, Section 2 will give a brief overview of the data needed to model these processes. Section 3 will set the theoretical background, with an emphasis on how to model and measure interregional spillovers and feedbacks of one region on other regions and back on itself. Section 4 will give an overview of a series of applications of interregional and international input–output studies that concentrate on producing results relevant for our understanding of the above-sketched processes of the fragmentation of production processes and their reorganization into interregional and international supply chains. Section 5 gives a summary evaluation in terms of further modeling developments that are needed.

2. ON THE CONSTRUCTION OF INTERREGIONAL INPUT–OUTPUT DATA

Methods for constructing regional and interregional input–output tables (IOTs) have been discussed in great detail in the literature; a recent update is provided in Miller and Blair (2009). The main problem is the near universal absence of *intra*-national, interregional trade data. In only a few countries (e.g. Japan, the USA and some European countries) are such data collected; in almost every other country, estimates have to be made based on assumptions about trade propensities (i.e. the volume of imports and exports) and an allocation mechanism has to be devised to assign imports and exports to the most probable trade partners. Even in cases where interregional trade data are available, the flows are often provided without differentiation as to whether they are intermediate or final goods and, in almost all cases, only flows of physical commodities are provided, requiring the complete estimation of trade in services.

In the international case the data situation is more or less the opposite. Countries assemble supply-and-use tables (SUTs) and import and export statistics, independently of each other, resulting in four different estimates for the same trade flows (see van der Linden and Oosterhaven, 1995, for a discussion and solution). Consequently, constructing international SUTs is a bottom–up process that concentrates on solving these data inconsistencies and adding the mostly unknown intra-country, sectoral destination of the international trade flows, just like the interregional case. Recently, a whole series of international SUTs has been constructed using different construction methodologies (see Dietzenbacher and Tukker, 2013 for a discussion). The most promising approach requires adding information on the relative reliabilities of the different data sources to solve these inconsistencies (Lenzen et al., 2012).

In contrast, the construction of interregional IOTs has almost always been a top–

down process. The methodologies used to estimate the interregional data in the absence of any observations have attempted to exploit the properties of trade balance, namely that exports from one region must be made consistent with the sum of imports from the remaining regions. Round (1983) was one of the first to do this in a two-region (Wales and the rest of the UK) context with a modified location quotient (LQ) approach, which avoids the implicit assumption of the simple LQ method that intra-industry trade (i.e. cross-hauling) does not exist. An additional modification to the *n*-region case was provided by Hulu and Hewings (1993). More recent efforts have centered on the development of modifications of bi-proportional techniques and those exploiting the properties of entropy maximization techniques (for a review, see Roy, 2004). In essence, the objective is to estimate the dyadic pairs of flows for an $n \times n$ matrix given only information about the vectors of exports and imports by sector from/to each region. In cases where some flow information is known (e.g. from freight surveys), the methodology focuses on estimates that produce flows that are as close as possible to the prior estimates but now respecting new sets of constraints,with Canning and Wang (2005) offering a flexible mathematical programming approach to reach that goal.

Moreover, since national IOTs are becoming rare, regional interindustry analysts increasingly are estimating interregional SUTs, which means that a choice has to be made from a whole family of possible interregional SUTs, not all of which have an accompanying interregional IO model (see Oosterhaven, 1984). The main choice is between estimating an interregional make table (products by producing industry) with single-region use tables, or an interregional use table (products by purchasing industry) with single-region make tables (see Jackson and Schwarm, 2011, for a further discussion). Eding et al. (1999) started this development with a full set of bi-regional SUTs for the Netherlands, while Lindall et al. (2006) and Schwarm et al. (2006) developed alternative methodologies to estimate consistent commodity flow matrices for interregional social accounting models (SAMs) for the USA. Robinson and Liu (2006) offer one of the few evaluations of these estimating techniques and their impacts on interregional multipliers.

3. INTERREGIONAL SPILLOVER AND FEEDBACK EFFECTS

In a series of articles, Miller (1966, 1969, 1986) introduced the notion of interregional feedback effects into the literature of regional analysis. In the simplest two-region case, output increases in region *r* may generate additional demands for imports from region *s*. To produce these exports from *s* to *r*, production in region *s* will need to expand. In turn, that will generate additional demands for imports from region *r*, which makes part of region *r*'s exports endogenous, as illustrated in Figure 18.1.

The solid boxes and arrows in Figure 18.1 indicate the structure of two identical single-region IO models. For region *r*, its well-known solution reads

$$\mathbf{x^r} = (\mathbf{I} - \mathbf{A^{rr}})^{-1}(\mathbf{Z^{rs}i} + \mathbf{f^r}) = \mathbf{L^r y^r} \tag{18.1}$$

with $\mathbf{x^r}$ = vector with total output by industry, $\mathbf{A^{rr}}$ = matrix with intraregional intermediate input coefficients, $\mathbf{Z^{rs}}$ = matrix with exports of intermediate outputs of

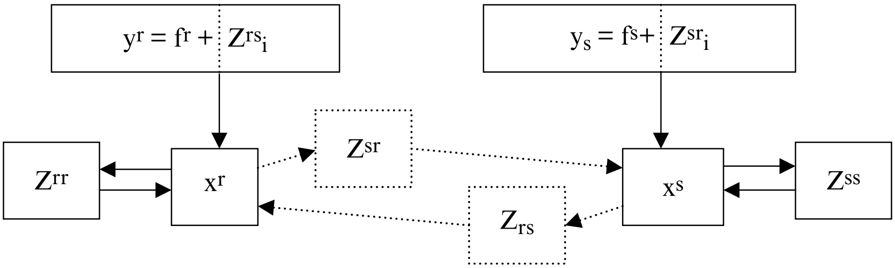


Figure 18.1 Joining two single-region IO models into one bi-regional IO model

region *r*'s industries to region *s*'s industries, $\mathbf{f^r}$ = vector with remaining final demand of region *r*, $\mathbf{L^r}$ = single-region Leontief inverse, $\mathbf{y^r}$ = single-region exogenous final demand.

The dotted boxes and arrows show what happens when the two single-region IO models are combined into one bi-regional IO model. Then, the formerly exogenous exports of intermediate goods and services are made endogenous by linking them to the output levels of the importing industries, by means of $\mathbf{Z^{rs}\, i} = \mathbf{A^{rs}\, x^s}$ and $\mathbf{Z^{sr}\, i} = \mathbf{A^{sr}\, x^r}$. The resulting bi-regional IO model has the following solution:

$$\begin{bmatrix} \mathbf{x^r} \\ \mathbf{x^s} \end{bmatrix} = \begin{bmatrix} \mathbf{I} - \mathbf{A^{rr}} & -\mathbf{A^{rs}} \\ -\mathbf{A^{sr}} & \mathbf{I} - \mathbf{A^{ss}} \end{bmatrix}^{-1} \begin{bmatrix} \mathbf{f^r} \\ \mathbf{f^s} \end{bmatrix} = \begin{bmatrix} \mathbf{B^{rr}} & \mathbf{B^{rs}} \\ \mathbf{B^{sr}} & \mathbf{B^{ss}} \end{bmatrix} \begin{bmatrix} \mathbf{f^r} \\ \mathbf{f^s} \end{bmatrix} = \mathbf{Bf} \tag{18.2}$$

with $\mathbf{B}$ = the bi-regional Leontief inverse. Note that the number of industries in region *r* does not need to be similar to that of region *s*. The intermediate import coefficient matrices $\mathbf{A^{rs}}$ and $\mathbf{A^{sr}}$, in that case, become rectangular, while the intraregional matrices $\mathbf{A^{rr}}$ and $\mathbf{A^{ss}}$ remain square.

Obviously, when exogenous final demand becomes smaller, the same output levels may be obtained only with larger intraregional multipliers, that is, $\mathbf{B^{rr}} > \mathbf{L^r}$. The difference is due to interregional feedback effects. Miller's initial intention was 'to suggest one method of quantifying the error that results from ignoring interregional linkages' (Miller, 1966, p. 106). To isolate the interregional feedbacks, he took the difference of the outcomes of the bi-regional and the single-region IO model with the same exogenous bi-regional final demand vector:

$$\text{Interregional feedbacks} = \mathbf{B^{rr}f^r} - \mathbf{L^r f^r} \tag{18.3}$$

and computed summary aggregated measures (norms) of the difference.

Miller's interpretation can be reconsidered in terms of an extended or augmented Leontief inverse, as initially suggested by Yamada and Ihara (1969). This interpretation can be further elaborated with the help of the Schur formula (Schur, 1917; Sonis and Hewings, 1993):

$$\mathrm{B} = \begin{bmatrix} \mathbf{B^{rr}} & \mathbf{B^{rr}A^{rs}L^s} \\ \mathbf{B^{ss}A^{sr}L^r} & \mathrm{B^{ss}} \end{bmatrix} = \begin{bmatrix} \mathbf{B^{rr}} & \mathbf{L^rA^{rs}B^{ss}} \\ \mathbf{L^sA^{sr}B^{rr}} & \mathrm{B^{ss}} \end{bmatrix} \tag{18.4}$$

where the matrices $\mathbf{L}^r$ and $\mathbf{L}^s$ represent the single-region Leontief inverses of the home and the foreign region (revealing intraregional effects), which enhance the impact of the matrices $\mathbf{A}^{sr}\mathbf{B}^{rr}$, $\mathbf{A}^{rs}\mathbf{B}^{ss}$, $\mathbf{B}^{rr}\mathbf{A}^{rs}$ and $\mathbf{B}^{ss}\mathbf{A}^{sr}$ that show the interregional spillover effects between the two regions (Miyazawa, 1976; see also Sonis and Hewings, 1995).

Further, the extended intraregional Leontief multipliers for the home and the foreign region equal the inverses of the so-called Schur complements $\mathbf{S}^r$ and $\mathbf{S}^s$:

$$\mathbf{B}^{rr} = (\mathbf{I} - \mathbf{A}^{rr} - \mathbf{A}^{rs}\mathbf{L}^s\mathbf{A}^{sr})^{-1} = (\mathbf{I} - \mathbf{S}^r)^{-1}$$

$$\mathbf{B}^{ss} = (\mathbf{I} - \mathbf{A}^{ss} - \mathbf{A}^{sr}\mathbf{L}^r\mathbf{A}^{rs})^{-1} = (\mathbf{I} - \mathbf{S}^s)^{-1} \tag{18.5}$$

The expression $\mathbf{A}^{rs}(\mathbf{I} - \mathbf{A}^{ss})^{-1}\mathbf{A}^{sr}$ identifies the self-influence feedbacks for region r. Clearly, the interregional feedback effects of the home region, in the bi-regional model, equal the product of two interregional spillovers (in causal order: $\mathbf{A}^{sr}$ and $\mathbf{A}^{rs}$), enhanced by the intraregional multipliers of the foreign region, as shown in (18.5) and in Figure 18.1. For the isolation of the interregional feedbacks, Miller thus compared $\mathbf{L}^r\,\mathbf{f}^r$ and $\mathbf{B}^{rr}\mathbf{f}^r = (\mathbf{I} - \mathbf{S}^r)^{-1}\mathbf{f}^r$. The same procedure can be used in the case of three- and four-region input–output systems (Miller, 1986).

In Miller's original work, the magnitude of the feedback effects for US regions was relatively modest – around 5 percent. The spillover effects were much larger and partly non-symmetric, the impact of change in region *r* on region *s* being much larger or smaller than the reverse impact. These results were confirmed early on for the Netherlands by Oosterhaven (1981). With a basic, Type I three-region IO model he found interregional feedbacks on regional GDP of only 1.1 percent for the relatively isolated rural Northern Netherlands and 3.4 percent for the strongly urbanized greater Rotterdam harbor region. With an extended, Type II model, with interregional commuting and interregional shopping, he found a larger aggregate underestimation of ignoring interregional feedback effects of, respectively, 3.1 percent and 6.6 percent. However, it should be taken into account that these early studies take error percentages with the total impact as base, which includes the direct effect for which no input–output or other type of model is needed. If only the indirect and induced effect had been taken as base, the more honest error percentages would have been more than twice as large.

An additional interpretation is possible by reference to the broader framework of feedback loops of economic self-influence (Sonis and Hewings, 1998b). In the two-region system, the interregional feedback loops appeared in an explicit form in the Schur complements, $\mathbf{S}^r$ and $\mathbf{S}^s$, and their corresponding extended intraregional Leontief inverses, $\mathbf{B}^{rr}$ and $\mathbf{B}^{ss}$. The component $\mathbf{A}^{rs}\mathbf{L}^s\mathbf{A}^{sr}$ represents a loop connecting both regions, while the component $\mathbf{A}^{sr}\mathbf{L}^r\mathbf{A}^{rs}$ presents a loop in the opposite direction. Further, the non-diagonal components of the extended Leontief inverse, $\mathbf{B}^{rr}\mathbf{A}^{rs}\mathbf{L}^s$ and $\mathbf{B}^{ss}\mathbf{A}^{sr}\mathbf{L}^r$, together also generate a closed loop. In an *n*-region input–output system, the interregional feedback loops of economic self-influence of region *r* present themselves in the component $\mathbf{B}_n^{rr}$ of the interregional Leontief inverse. Other loops, involving the remaining regions, *s*, can be constructed with the help of the non-diagonal components of the Leontief inverse, $\mathbf{B}_n^{rs}$ (see Sonis and Hewings, 1988a).

Feedback loops provide the building blocks for the identification of the myriad economic interactions within an input–output system. In a multiregional system, methods are now available to first identify the spatial paths of influence across regions (Sonis and Hewings, 1988b), and to then proceed with a hierarchical extraction to identify the spatial paths in terms of the order of their economic importance (Sonis et al., 1997). Thus, if feedback effects prove to be important, the methods presented here will highlight the nature and significance of the paths of influence across the interregional system. Since this methodology provides insights into the geographic structure of these interregional flows, it can be extended to reveal more sophisticated trade patterns by moving from bilateral feedback loops to trilateral and multilateral loops. Further, feedback loop analysis offers a method of placing feedback effects on a network (see Sonis and Hewings, 1988a, 1988b).

4. APPLICATIONS

4.1 Changing Nature of Trade

Recent analysis of the Chicago regional economy over time discovered a hollowing-out process whereby intraregional transactions were being replaced by interregional flows (Hewings et al., 1998). However, more detailed analysis (Romero et al., 2009) revealed that, while the hollowing-out process was occurring for the economy as a whole, selected production chains appeared to be becoming more complicated. Further analysis of the structure of these interregional flows in the Midwest (a region of five US states) revealed patterns that could not be explained by the usual appeals to comparative advantage. A large percentage of the flows were intra-industry across states, reflecting a tendency to exploit economies of scale through specialization in a small range of products within one industrial sector (see Hewings et al., 1997).

In fact, the increase in specialization discovered by Romero et al. (2009) accords with a tendency for the number of secondary products produced by any one establishment to have decreased. In essence, firms have changed the organization of their production systems by the fragmentation of production into more specialized blocks, with the concomitant effect that these intermediate stages then require trade, often across state lines, before entering their final assembly in a finished good. At an aggregate level, states or metropolitan areas appear to become more similar in structure; but within more detailed categories, such as fabricated metals, for example, there is often significant specialization of processes or products across plants.

In an extensive overview of the literature on the European Union (EU), supplemented by their own research, Los and Oosterhaven (2008) find comparable results from the five-yearly intercountry input–output tables for the EU for 1965–95. They observe a concentration of industry (according to location theory), along with a specialization of domestic demand (the home market effect of Krugman, 1991, and Porter, 1990), a specialization of exports (according to classical trade theory) and the growth of intra-industry trade (according to new trade theory). The paradox of having both increasing specialization of exports and increasing intra-industry trade is solved by an increasing specialization of imports in the same direction as the exports, indicating an increase in outsourcing along the diagonals of the bilateral input–output trade matrices (see van der Linden and Oosterhaven, 2000). This explanation is reinforced by the dominance of intra-industry trade in intermediate products as opposed to the dominance of inter-industry trade in final goods and services.

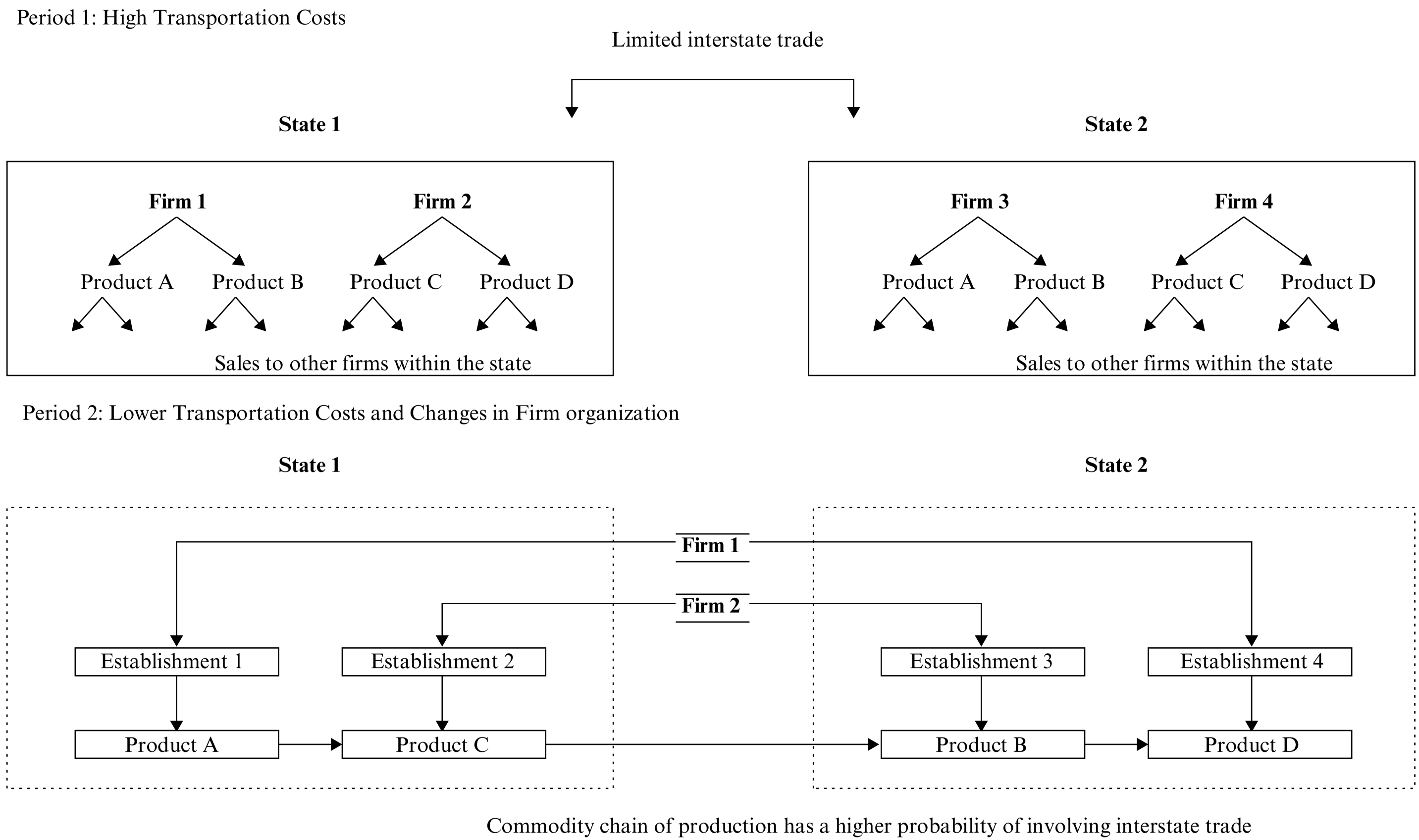
The new economic geography extension of new trade theory, both initiated by Nobel Laureate Paul Krugman (see Fujita et al., 1999), stresses three drivers of the spatial economy: (1) economies of scale; (2) transportation costs; and (3) a preference for having multiple, close substitutes locally available to both consumers and producers (in short: 'love of variety'). To these, one might add the changing role of ownership (firm consolidation) with most plants now being part of multiregional or multinational enterprises. In the last three decades, transportation costs in real terms have declined significantly, with the result that firms have been able to organize their supply chains to optimize production and distribution processes (see Oosterhaven and Rietveld, 2005).

The schematic process is illustrated in Figure 18.2; with high transportation costs, market areas were limited and thus the ability to exploit scale economies was circumscribed. As a result, each establishment often produced multiple products; with the lowering of transportation costs, intra-establishment specialization took place, often prompted by changes in firm ownership, with the result that interstate trade increased. The main implication of these changes is an increase in the magnitude of interregional spillover and feedback effects. In addition, especially trade in intermediate goods and services, as a result of the specialization process just noted, is increasingly dominated by intra-industry rather than interindustry trade (see Munroe et al., 2007; Hewings and Parr, 2009).

The increase of spillover effects may be illustrated by means of the intercountry IO data for the EU. Starting from a relatively low level in 1959, both the spillovers to the rest of the EU (RoEU) and those to the rest of the world (RoW) have risen considerably, with the spillovers to the RoEU growing faster in the early period 1959–70 (Oosterhaven, 1995), and those to the RoW growing faster in the later period 1970–85 (van der Linden and Oosterhaven, 1995). Aside from the increasingly global outsourcing of part of production processes, the reverse of the growth rates for intra-EU and extra-EU trade is also due to the two oil price hikes and the extension of the EU with three new members in the 1970s. Recent research (Bouwmeester et al., 2014) shows that first-round intra-EU income spillovers of the 27 EU members are still rising over the period 2000–2007 to a sectorally weighted average of almost 6 percent, and that higher-order intra-EU spillovers and feedback effects have risen to almost 8 percent. Note that the total of 14 percent has to be more than doubled to get a fair impression of the size of these intercountry spillovers and feedbacks relative to the domestic indirect effects.

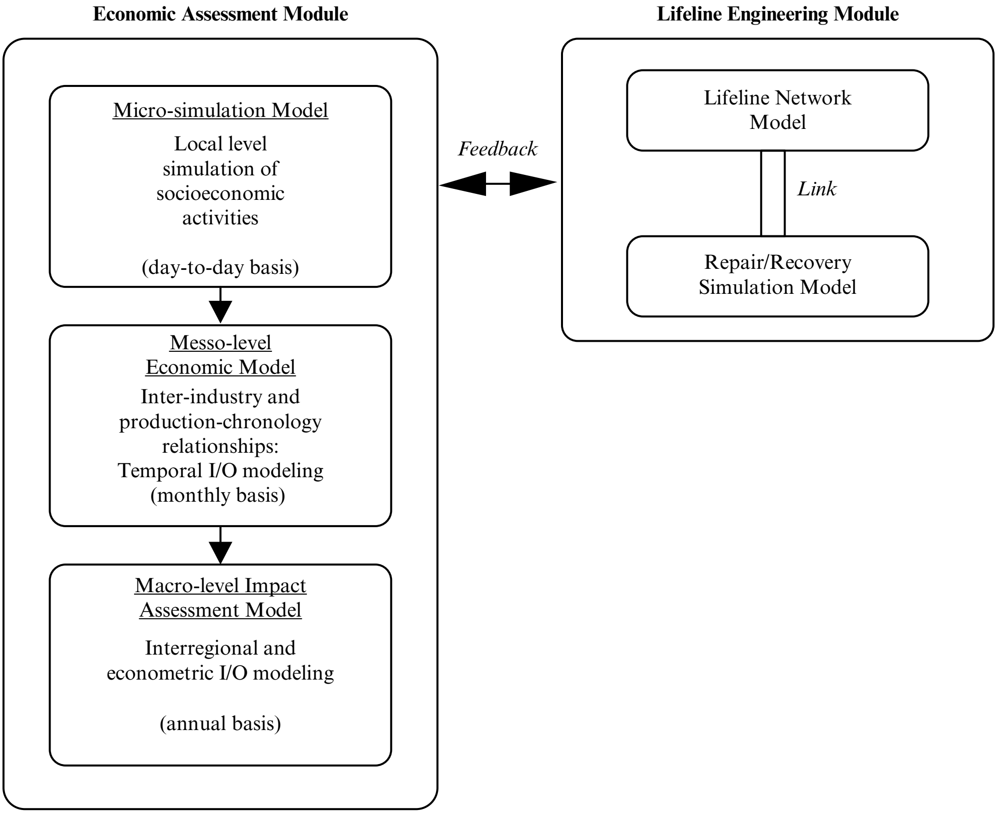
4.2 Indirect Effects from Unexpected Events

Recent earthquakes have emphasized the need to consider indirect effects on other regions within an economy and on other countries through international trade. Okuyama et al. (1999, 2004) found larger indirect impacts in the rest of Japan from the Kobe earthquake than in the Kinki region in which the earthquake occurred. Appropriate recovery and reconstruction plans, especially on interregional lifeline damages (e.g. to water and electricity supplies), are necessary to minimize the further indirect effects and to plan a smooth and timely recovery process for the economy (see Figure 18.3).



Source: Parr et al. (2002).

Figure 18.2 Changing spatial organization of firms



Source: Okuyama et al. (2004).

Figure 18.3 Interregional modeling in economic–engineering lifeline assessment modeling

Table 18.1 shows the income effects from the Great Hanshin earthquake of 1995; note the magnitude of the interregional effects, especially when reconstruction effects are included. The magnitudes in the rest of Japan are often much larger, reflecting the important role that the disruption played in severing many critical supply chains that involved Kinki–rest of Japan trade as well as the limitations on exports both from within Kinki and the rest of Japan that resulted from damage to port facilities.

4.3 Regional Development Policies: A Tale of Two Countries and the US Midwest

Indonesia and Brazil are two countries with very significant disparities in levels of income/welfare between regions. Decades of policy initiatives have failed to narrow these differentials; with the help of a set of interregional input–output tables, it was possible to identify a significant source of failure of past policies.

Looking at the Indonesian case, building a five-region multiregional input–output

Table 18.1 Interregional income effects of Great Hanshin Earthquake of 1995, ¥ billion (1995)

Region of Income Receipt	Region of Income Demand		
	Kinki	Rest of Japan	Total
Kinki	−936 190	−1 168 787	−2 104 977
	1 108.274	−1 168 787	−60 513
Rest of Japan	−738 664	−937 145	−1 675 809
	814 125	−937 145	−123 020
Total	−1 674 853	−2 105 932	−3 780 785
	1 922 400	−2 105 932	−183 532

Note: Upper row: without reconstruction demand. Lower row: with reconstruction demand.

Source: Okuyama et al. (1999).

model enabled estimation of how changes in one region would spill over to other regions (Hulu and Hewings, 1993). The results revealed that intraregional impacts of a change in final demand always are larger than 70 percent when the direct change occurs in Java (the most prosperous region). With the exception of agriculture, for the Eastern Islands (the least prosperous region) less than 30 percent of the indirect effects remains within the region. Further, for Java, interregional outflows are small while interregional inflows are large; the reverse is true for the Eastern Islands. Thus there is an important asymmetry in impacts that exacerbates the existing differentials, generating forces that continue to push the disparities upwards. These results are summarized in Table 18.2.

Similar findings were evident in Brazil (Guilhoto et al., 2002); in this case, a two-region model (Northeast, rest of Brazil) provided a similar pattern of asymmetry to the one revealed in Indonesia. Sectors in the Northeast of Brazil (where per capita income is about 50 percent of that in the more prosperous Southeast around São Paulo) are much more dependent on inputs from the rest of Brazil than the reverse. Accordingly, economic expansion in the Northeast – promulgated by federal and state programs – generates enormous benefits to the rest of the country (upper part of Figure 18.4), while expansion in the rest of Brazil provides limited benefits to the Northeast (lower part of Figure 18.4).

If one was to compare two regions, Northeast of Brazil and Midwest of the USA, with similar shares of their respective national GDP totals (15 percent for NE Brazil, 16 percent for Midwest USA), one might ask whether the expectation would be for similar outcomes. As noted earlier, in the Midwest of the USA, with higher levels of development, there are larger volumes of trade with a much lower percentage of interindustry trade. In contrast, the volume of trade within the Northeast of Brazil would be considerably smaller than within the Midwest USA, and highly concentrated in interindustry trade, which generates a level of interaction among the Midwest US states that is much larger than the level of interaction among the Northeast Brazil ones.

Figure 18.5 presents a stylized summary of the relationship between per capita income and the volume of trade on the one hand and the nature of this trade (intra- versus interindustry) on the other hand. With increasing per capita income, one would expect trade to increase; but as it increases, the composition changes to become dominated by

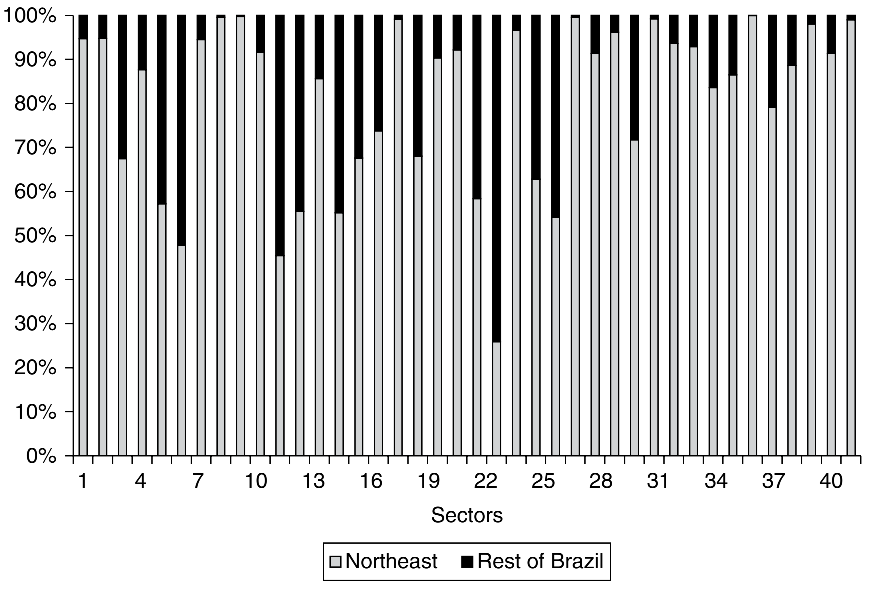
Table 18.2 Effects of a final demand impulse in Java and in the Eastern Islands

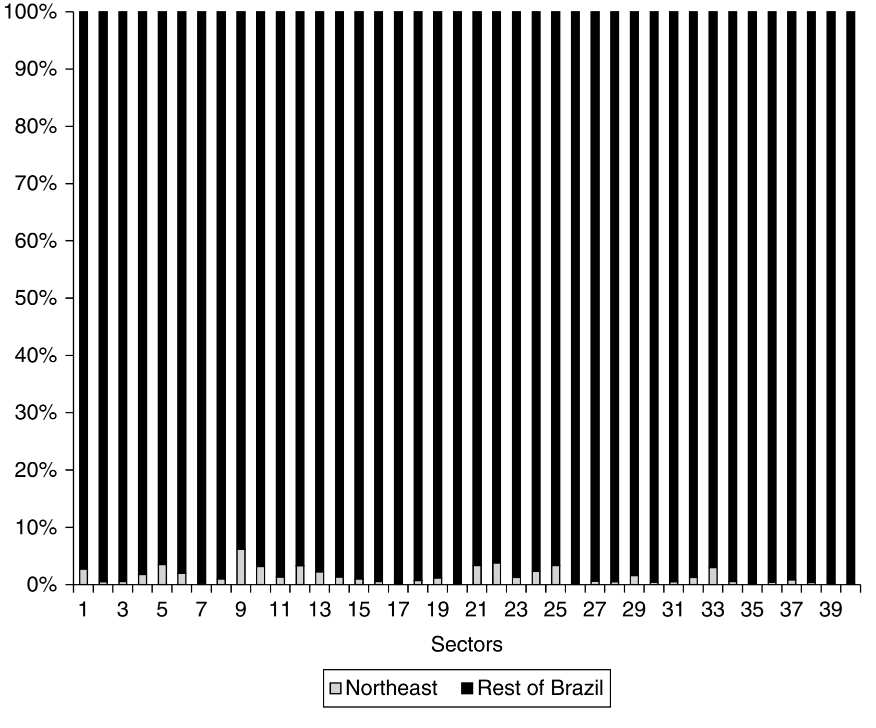
Sector	Sumatera	Java	Kaliman	Sulawesi	Eastern Islands	Inter Regional Sum
Java						
1	6.4	83.2	2.7	3.6	3.3	17.8
2	17.2	72.4	7.2	1.0	1.9	27.6
3	14.0	74.5	5.9	2.4	2.9	25.5
4	6.1	89.0	2.6	1.0	1.1	11.0
5	8.9	83.9	3.8	1.4	1.7	16.1
6	5.0	89.0	2.1	1.6	1.6	11.0
7	4.1	92.2	1.7	1.0	1.0	7.8
8	3.0	94.2	1.3	0.5	0.6	5.8
9	4.2	92.3	1.8	0.7	0.7	7.7
10	–	100.0	–	–	–	–
11	5.4	89.6	2.3	1.1	1.3	10.4
Eastern Islands						
Sector	Sumatera	Java	Kaliman	Sulawesi	Eastern Islands	Inter Regional Sum
1	20.7	21.0	9.2	4.7	43.9	56.1
2	32.8	33.3	14.5	7.5	10.8	89.2
3	29.4	28.9	13.0	6.7	21.8	78.2
4	34.1	34.4	14.7	7.7	8.9	91.1
5	33.5	32.8	14.9	7.9	10.7	89.3
6	28.9	29.6	12.7	6.9	21.3	78.7
7	31.0	30.9	13.8	7.0	16.8	83.2
8	29.0	30.1	12.5	7.5	20.5	79.5
9	25.0	26.3	10.8	6.1	31.3	68.7
10					100.0	
11	33.7	33.3	15.0	7.9	9.9	80.1

Source: Hulu and Hewings (1993).

intra-industry trade. This change is made possible by reductions in transport cost and the shift of the more homogeneous, simple primary resources production to the more complex production of heterogeneous manufacturing products, which changes the organization of production into a more fragmented form. Among the five Midwestern states shown in Table 18.3, interstate trade was over $400 billion; much of the increase in volume of this trade can be traced to the process of fragmentation discussed earlier. A stylized summary is provided in Figure 18.6.

Lower transport costs and the benefits of economies of scale would see the transformation of production from a dominant intrastate to an interstate system; fragmentation thus generates a significant boost to the volume of interstate trade. However, increased interdependence, while a positive outcome during times of growth, can generate patterns of dependence during downturns. Some 20 percent of the job losses during the Great Recession were concentrated in the Midwest; the interdependence characterized by





Source: Guilhoto et al. (2002).

Figure 18.4 Asymmetry in indirect impacts in Brazil: Northeast versus rest of Brazil: upper figure, NE; lower figure, rest of Brazil

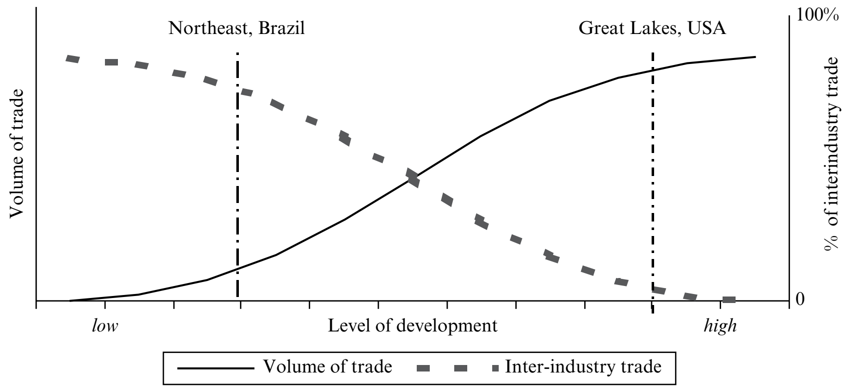


Figure 18.5 Stylized relationships between regions at different levels of development

Table 18.3 Midwest interstate trade, 2007

	Domestic ($ billion)	Foreign ($ billion)	Total ($ billion)	% Foreign	% Domestic	% Domestic Midwest
Illinois	399.91	48.90	448.81	10.89	89.11	32.40
Indiana	252.02	25.96	277.98	9.34	90.66	33.82
Michigan	226.88	44.56	271.43	16.41	83.59	32.29
Ohio	369.82	42.56	412.39	10.32	89.68	27.62
Wisconsin	172.13	18.83	190.95	9.86	90.14	33.19

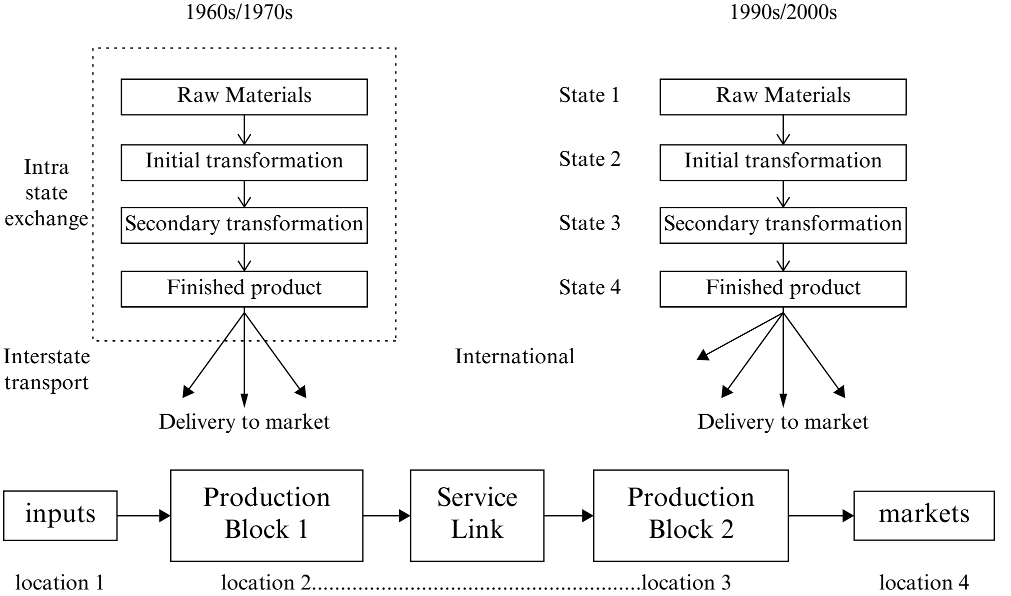
Source: Hewings and Parr (2009).

Figure 18.6 resulted in a further concentration of indirect job losses. Anywhere from 20 to 30 percent of the indirect losses from jobs in one Midwestern state were concentrated in the other four states.

4.4 The Role of Changes in Interregional Trade in a Mature Economy: Japan 1980–90

Do the processes of change, as found in the Midwest of the USA, vary over time? Using a modified interregional model of Japan, analysis explored the role of trade in generating impacts across the regions (see Hitomi et al., 2000). Following Yamada and Ihara's (1969) notion of an enlarged Leontief inverse, an interregional input–output model was developed for 1980, 1985 and 1990. The changes between these time periods in gross output by region were decomposed into three parts: contribution of changes in (1) domestic purchasing coefficients; (2) interregional trade coefficients; and (3) technical coefficients.

The intraregional multiplier declined over the period 1980–90; the major factor accounting for the decline in the intraregional multiplier is clearly the dispersing of interregional trade. All the regions reduced intraregional purchases and dispersed their interregional trade; interregional purchases from Kanto (the Tokyo centered region) in particular increased significantly. This evidence indicates that the dependence of other



Source: Hewings and Parr (2009).

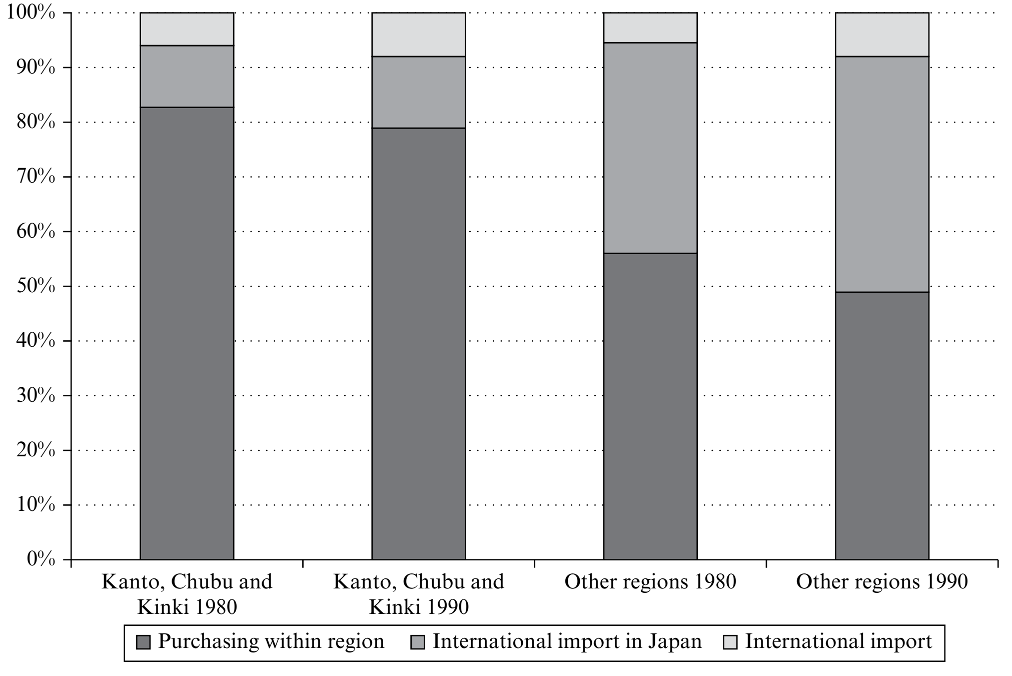
Figure 18.6 Stylized representation of the spatial reorganization of production due to fragmentation

regions on the Kanto region increased during this period, supporting Akita's (1999) findings. International imports have little effect at the regional level, whereas the changes generated by interregional trade are much more important. Furthermore, while the effect of interregional trade was dispersing and intraregional multipliers were decreasing, the contribution of technology change declined in importance.

These findings provide support for an earlier study by Okazaki (1989), who reported that the degree of intermediation in the Japanese economy as a whole had begun to decline; he referred to this process as a 'hollowing-out' effect. Figure 18.7 provides a summary of the changes for selected regions: while the relative changes varied, there was little change in the contribution of international imports to production. By far the largest sources of change were in the increase in interregional flows and a decrease in intraregional flows.

4.5 Interregional Flows within Metropolitan Regions

Are the nature and importance of interregional flows similar at different spatial scales (e.g. between trading partners internationally, between regions within a country and between central cities and suburbs within a metropolitan region)? As one moves down this hierarchy, additional interregional flows appear. To examine the changing nature and importance of these flows, an interregional model was developed for a four-fold division of the Chicago region (Hewings and Parr, 2007); the analysis examined, sequentially, the flows of goods and services, the flows of income from labor (the reverse



Source: Hitomi et al. (2000).

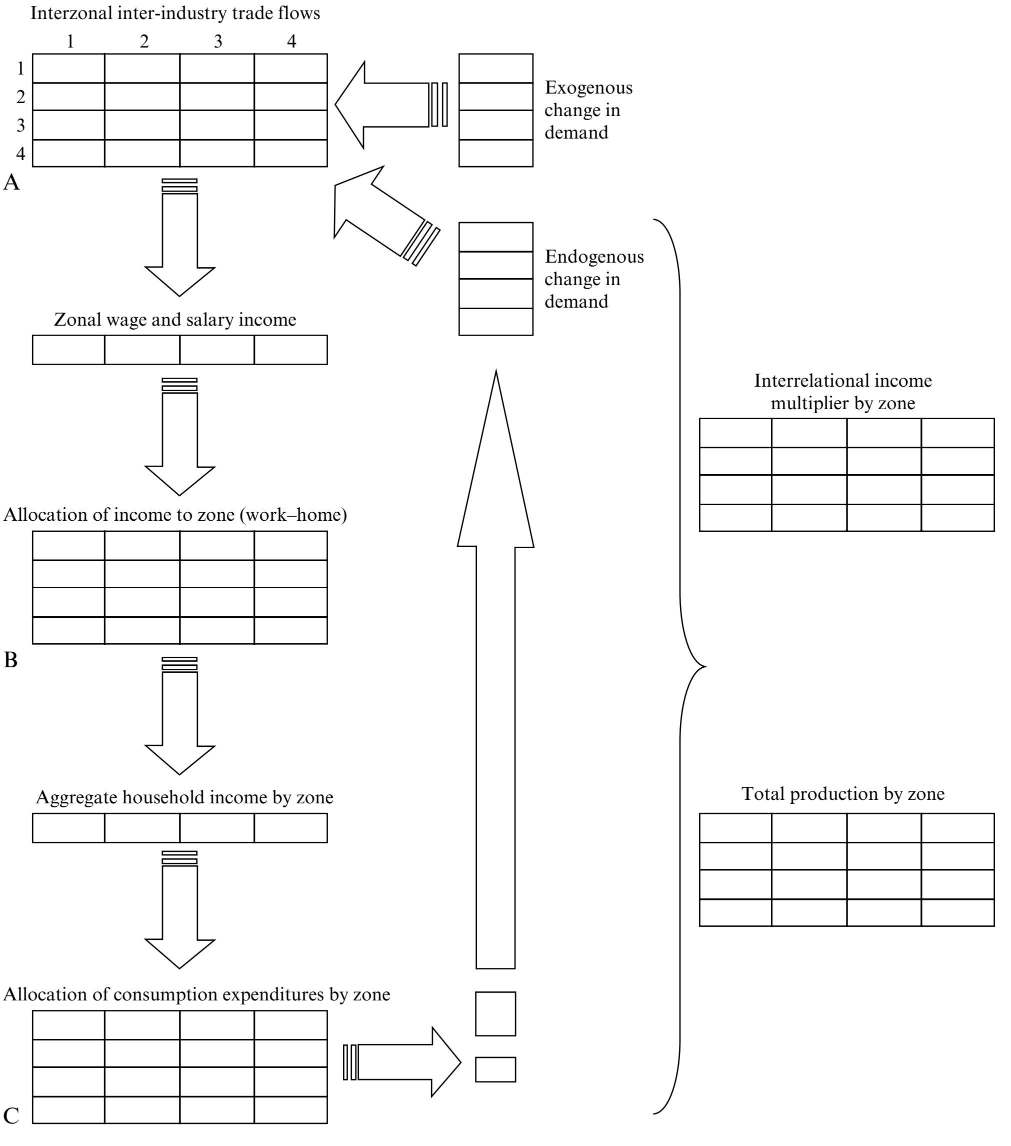
Figure 18.7 Summary of changes in the origins of intermediate inputs, Japan, 1980–90

of commuting flows) and finally the shopping flows of expenditures from these incomes. Figure 18.8 provides a stylized representation of the sequence.

Intrazonal flows dominate the production relationships in the assembly of goods and services within the Chicago region (see Figure 18.9). Accordingly, net flows (inflows minus outflows) are modest in size, with Zone 1 (central business district) and Zone 4 (outer suburbs) being net importers, and Zone 2 (the rest of the city of Chicago) and Zone 3 (inner suburbs) being net exporters. Somewhere between 90 and 94 percent of the direct and indirect effects of intra-metropolitan trade remain within a zone.

When the effects of income transfers from place of work to place of residence are added together with the spatial impacts of shopping expenditures on retail goods from these incomes; that is, when one moves from a Type I model to a Type II interregional IO model (Oosterhaven, 1981; Miller and Blair, 2009), a very different pattern of interregional interdependence emerges (see Figure 18.10). With the exception of Zone 4, less than 50 percent of the total production impacts can be traced, directly and indirectly, to activity that is generated within each zone. For Zone 4, there is a greater degree of self-sufficiency, but even here, 36 percent of the system-wide production effects in this zone can be traced to demand from other zones.

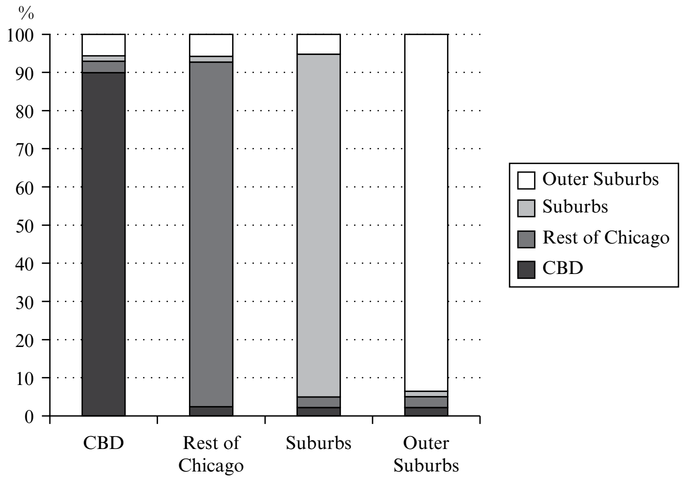
While the patterns of increasing trade dependencies observed at the international level are found at the regional level within countries, the flows of goods and services, complemented by locally important flows of labor (commuting and migration) and flows of



Source: Hewings and Parr (2007).

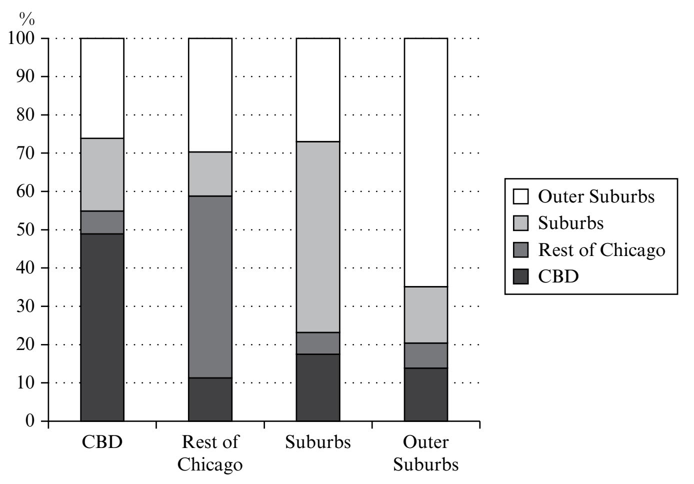
Figure 18.8 Sequential structure of interdependence in a metropolitan region

retail expenditures, generate an enhanced pattern of interdependence within metropolitan areas. Spillovers and feedbacks inside the metropolitan regions are relatively larger and more complicated than those observed between regions within a country. However, over time, even these interdependencies will be enhanced by movements of income associated with migration.



Source: Hewings and Parr (2007).

Figure 18.9 Interzonal flows of goods and services, Chicago, 2000



Source: Hewings and Parr (2007).

Figure 18.10 Total interzonal Type II multipliers, Chicago, 2000

4.6 Interregional Models and Supply Chains

Work at the country level (e.g. Fukasaku et al., 2011) has revealed greater country integration in Asia as a result of the fragmentation of production. Further, outcomes of an interregional input–output (IRIO) model for China (see Pei et al., 2011) have shown that the position of regions in the interregional and international supply chain is

Table 18.4 Density, GDP/capita and positions in the interregional supply chain, China, 2002

	Northern Municipalities	East Coast	South Coast	North East	North Coast	North West	Central Region	South West
Population density	864	648	361	133	456	31	351	77
GDP/capita	26.67	17.84	15.33	10.68	10.30	6.67	6.29	5.20
Net inter-regional spillovers	−5.3	+74.3	+139.3	−15.9	−50.5	−17.2	−95.7	−29.0

Note: Density = inhabitants/km^2, GDP/capita = 1000 RMB/inhabitant, net spillovers = billion RMB of value added generated in other regions due to own foreign exports –/– own value added due to foreign exports of other regions.

Source: Pei et al. (2011).

strongly related to the level of their income per capita. Chinese inland regions provide inputs to the more centrally located regions, which provide inputs to the coastal regions that service international markets. About the same rank order is found for regional GDP per capita in Table 18.4, although the net interregional spillover measure used is sensitive to the economic size of the region at hand. The highest GDP/capita spoils the relation; however, it is found for the capital region that collects tax income from all over China, while it is only loosely tied into the various interregional and international supply chains.

As the examples above show, there is an important opportunity to marry the insights of supply chain modeling with the information available from interregional IO models. For example, one might expect to see a decrease in the diagonal elements of an IRIO table as production chains transform to greater establishment-to-establishment flows. However, the process is unlikely to be homogeneous, since there will be a trade-off between the increases in spatial complexity (generating perhaps micro clusters) and the increase in spatial fragmentation of the kind revealed by Romero et al. (2009) for Chicago. Further, there is a disconnect between the analysis of many supply chains in the business literature, where the focus is often on optimization methods, and input–output analyses that focus on the nature and strength of associated interindustry linkages or issues associated with location of facilities.

Hence there is a clear role for CGE models with a quasi-optimization structure but with appropriate modifications to handle supplier source (by location); while this choice might be determined by relative prices, there is evidence that supply chains require specific volume, quality and delivery schedules as well as fixed prices. CGE nested production functions would have to accommodate the non-competitive nature of the input structure in the short run (fixed contracts that extend over several years). The recent experience of Toyota and Honda in handling disruptions in their supply chains suggests that there are often no possibilities for input substitution, neither technically nor spatially.

The challenge becomes one of assessing risk, flexibility, the degree of redundancy and the optimal location of alternatives in providing a more balanced assessment of the options. Issues such as coordination (sequencing), timing and risk are space-time issues that have rarely been addressed in input–output modeling. There is also an important class of temporal linkages that has yet to be examined; the interregional value chain impacts associated with the purchase of an automobile will generate a series of future demands for gasoline, servicing, insurance and so on that may have very different sectoral and spatial compositions. In some cases, the supply chains may be multidimensional with entirely different space-time compositions.

There would appear to be an opportunity to modify some existing methods to address the needs of supply chain analysis. For example, the average propagation length (APL) idea of Dietzenbacher and Romero (2007) could be modified to account for simultaneity across value chains. The Dietzenbacher and Los (1998) hypothetical extraction method could be used, in conjunction with a modified APL to simulate the effects of disruption in one or more components of the chain. Similarly, the Sonis and Hewings (1992) development of a field of influence of change provides an opportunity to examine (in an IRIO) the spatial reach of disruption; harnessing this idea with the temporal Leontief inverse might provide an approximation to the space-time processes of change (Sonis and Hewings, 1998). Finally, the multi-period nature of households' purchases that generate future demands for ancillary services offers an opportunity to look again at sequential input–output modeling (Romanoff and Levine, 1986; Okuyama et al., 2004).

5. SUMMARY EVALUATION

As regions become both more competitive and more interdependent (complementary) over time, it will become even more critical to gain an understanding of (1) the nature and importance of external trade for a given region; (2) the geography of this trade – intraregional versus interregional versus international – and the diversity of the trading partners in terms of demands and location; and (3) the sustainability and reliance of these trading relationships (i.e. a region's exposure to disruptions). Without access to interregional input–output information, it will be very difficult for policy analysts to consider ways of enhancing a region's competitiveness.

The increasing sophistication of supply chain systems presents another reason for the importance of interregional input–output models, as they are indispensable to capture the system-wide impacts of changes in supply chain components. The need now is for more integration of the optimization methodology of supply chain modelers with the system-wide perspectives provided by interindustry analysts. The space-time dimensions will become critical given the wide spatial reach of many supply chains and the increasing role of coordination and sequencing of activities. The input–output toolbox offers many methods that can help provide insights into the ways in which the impacts of supply chain disruptions spread across multiregional economies and thus help to explain the degree to which a single region's economy can withstand significant interruptions to production.

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