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Abstract

Data for the Chinese province of Hubei are used to assess the performance of Kronenberg's CHARM, a method that takes explicit account of cross-hauling when constructing regional input−output tables. A key determinant of cross-hauling is held to be the heterogeneity of the products of individual sectors, which is estimated using national data. However, contrary to the authors' earlier findings for Finland, CHARM does not generate reliable estimates of Hubei's sectoral exports, imports and volume of trade. It is crucial, therefore, especially in relatively small regions, to make adequate allowance for any known divergence between regional and national technology and heterogeneity.

Keywords: Regional input−output tables; Non-survey methods; CHARM; Cross-hauling; China

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1. INTRODUCTION

Regional input–output tables are a very useful tool for regional planning, yet constructing a survey-based regional table can be a complex, expensive and lengthy task. Consequently, regional tables based primarily on survey data are rare. Typically, therefore, analysts endeavour to 'regionalize' the national input–output table, so that it corresponds as far as possible to the industrial structure of the region under consideration. Making sufficient allowance for interregional trade is crucial, as failure to do so is apt to yield very misleading regional sectoral multipliers. Indeed, as noted in the next section, many studies have demonstrated that conventional methods of regionalization – especially those based on the commodity balance (CB) method or on simple location quotients (SLQs) – substantially understate interregional trade. This understatement is primarily due to the fact that these methods do not recognize *cross-hauling* (the simultaneous exporting and importing of a given commodity). They also do not allow explicitly for a region's relative size; this is important because cross-hauling is prone to be more acute in smaller regions than in larger ones.

In an effort to tackle the problem of cross-hauling, Kronenberg (2009) proposed an innovative new non-survey routine for constructing regional tables, namely the Cross-Hauling Adjusted Regionalization Method (CHARM). CHARM incorporates a systematic procedure for adjusting the volume of imports and exports to allow for cross-hauling, based on the postulate that the amount of cross-hauling varies directly with the heterogeneity of products, as well as with regional output and demand (Kronenberg, 2009, p. 50).

Whereas abundant empirical evidence exists on the relative performance of the SLQ and related techniques, little is known about the likely effectiveness of CHARM as a way of regionalizing national input–output tables. In fact, the only empirical studies currently available are those by Flegg and Tohmo (2013a), who examined data for Finland and its largest province, Uusimaa, and Kronenberg and Többen (2013), who studied data for the

German federal state of Baden−Württemberg. More tests are clearly needed, especially for countries that are less economically advanced than Finland and Germany.

A notable exception to the paucity of survey-based regional tables is China, where regional tables for most provinces and municipalities are constructed at five-yearly intervals. This study focuses on the province of Hubei, which was chosen owing to its diversified regional economy and key position in central China, along with the extensive knowledge of Hubei's economy of one of the present authors. Our primary aim is to use the published tables for Hubei and China to carry out a detailed empirical test of CHARM's performance. As far as the authors are aware, this is the first study to have used Chinese data in this way.

The present study builds upon the work of Flegg and Tohmo (2013a) in two important respects. The first is that Finland and China are at very different stages of economic development and they also differ greatly in terms of both population and area. It is of interest, therefore, to see whether these disparities have an impact on CHARM's effectiveness. Secondly, the input−output table for Hubei is more detailed than that for Uusimaa, with forty-two rather than twenty-four sectors, including seventeen separate types of manufacturing. This finer detail makes it possible to perform a more searching analysis.

The rest of the article is structured as follows. The next section explores the theoretical foundations of CHARM and attempts to put it into context. Alternative approaches are also briefly considered. This is followed by an overview of Hubei's economy. SLQs are then used to highlight any salient differences or similarities in the regional and national economic structures. The fourth section examines the key features of CHARM, while the fifth section explains how this method was used to estimate Hubei's exports, imports and volume of trade. In the subsequent two sections, we assess how well CHARM is able to simulate interregional trade and sectoral supply multipliers. The penultimate section considers possible ways of enhancing the performance of CHARM and the final section concludes.

2. CROSS-HAULING AND NON-SURVEY METHODS

CHARM is an example of a pure non-survey technique, whereby a very limited amount of region-specific data (such as sectoral employment) is used to regionalize the national input–output table in the initial stages. Although these first steps are entirely mechanical, it is possible for analysts subsequently to incorporate superior data in an effort to improve their models. Regionalization via the use of location quotients (LQs) is another example of a pure non-survey technique.

Since CHARM is a refinement of the classical CB approach to constructing a regional input–output table (Isard, 1953), it is appropriate to begin by considering the key concepts underlying this approach. At the outset, the analyst would need to use the following formula to estimate the demand for each regional sector:

$$dt_i^r = \sum_j a_{ij} x_j^r + df_i^r, \tag{1}$$

where dt_i^r is the total regional demand for commodity i in region r, a_{ij} is the national technical coefficient (the number of units of commodity i, irrespective of source, needed to produce one unit of gross output of industry j), x_j^r is the regional output of commodity j, $\sum_j a_{ij} x_j^r$ is intermediate demand, and df_i^r is final demand. A key postulate here is that the region and the nation share the same technology. Where regional sectoral output is unknown, as is often the case, employment can be used as a proxy.

If $dt_i^r < x_i^r$, the entire surplus is assumed to be exported; conversely, if $dt_i^r > x_i^r$, it is presumed that sufficient imports will be available to make up for the shortfall in regional output. The simultaneous importing and exporting of commodity i is ruled out *a priori*; in other words, cross-hauling is assumed not to occur. The CB method operates on the principle of maximum local trade, i.e. 'if commodity i is available from a local source, it will be purchased from that source' (Harrigan et al., 1981, p. 71). One problem with this principle is that it 'ignores the fact that any industry commodity in practice will be an aggregation of a number of quite distinct commodities' (*ibid.*), so that cross-hauling is almost bound to occur. Other reasons for anticipating cross-hauling, in terms of product differentiation and so on, are discussed later in this article.

The CB method can be used to estimate a set of regional input coefficients, the r_{ij}, as follows: if $dt_i^r < x_i^r$, then $\hat{r}_{ij} = a_{ij}$; conversely, if $dt_i^r > x_i^r$, then $\hat{r}_{ij} = (x_i^r / dt_i^r) \times a_{ij}$ (cf. Robison and Miller, 1988, p. 1524). This procedure is comparable with what happens when SLQs are used for purposes of regionalization. The SLQ for commodity i is defined as:

$$SLQ_i \equiv \frac{x_i^r / \Sigma_i x_i^r}{x_i^n / \Sigma_i x_i^n} \equiv \frac{x_i^r}{x_i^n} \times \frac{\Sigma_i x_i^n}{\Sigma_i x_i^r}, \qquad (2)$$

where x_i^r is regional output in sector i and x_i^n is the corresponding national figure. $\Sigma_i x_i^r$ and $\Sigma_i x_i^n$ are the respective regional and national totals. With the SLQ, the r_{ij} are estimated by applying the rules: if $SLQ_i > 1$, then $\hat{r}_{ij} = a_{ij}$; conversely, if $SLQ_i < 1$, then $\hat{r}_{ij} = SLQ_i \times a_{ij}$.

It can be demonstrated that the SLQ and CB routines will generate equivalent results if $x_i^r = x_i^n \times s^r$ and $df_i^r = df_i^n \times s^r$, where $s^r \equiv \Sigma_i x_i^r / \Sigma_i x_i^n$ is a measure of the region's relative size (cf. Robison and Miller, 1988, p. 1525). In other words, the two methods will yield equivalent results if regional sectoral output and final demand are scaled down versions of the corresponding national values. This is a strategy that analysts are liable to pursue, although they would normally use employment as a proxy for output. The SLQ and CB methods are, therefore, just as prone to be affected by the problem of cross-hauling.

In principle, the cross-industry location quotient (CILQ), as defined below, can be used to address the problem of cross-hauling:

$$CILQ_{ij} \equiv \frac{SLQ_i}{SLQ_j} \equiv \frac{x_i^r / x_i^n}{x_j^r / x_j^n}. \quad (3)$$

With this formula, the elements in each row of the national coefficient matrix are adjusted in accordance with the relative regional importance of the supplying sector i and purchasing sector j. This variable adjustment permits cross-hauling since some purchasing sectors can be deemed to be importers of commodity i (those where $CILQ_{ij} < 1$), whereas others can be designated as exporters (those where $CILQ_{ij} \geq 1$). Unfortunately, the evidence suggests that the CILQ fails to make adequate allowance for cross-hauling and hence still greatly understates interregional trade (Harrigan et al., 1981). Indeed, the SLQ, CILQ and CB methods all yield highly unsatisfactory empirical results and there is little to commend any one of them as a regionalization technique (*ibid.*).

Given the inability of the CB and SLQ methods to capture cross-hauling, along with the serious shortcomings of the CILQ in this respect, several alternative approaches have been proposed. Before examining some of these approaches, we should note the observation of Richardson (1985, p. 613) that '[a]lthough industrial disaggregation helps to relieve the cross[-]hauling problem, it does not solve it.'

With respect to the CB method, Jackson (1998, p. 234) suggests that adjustments for cross-hauling could be made in two different ways: (i) via the manual insertion of superior data on regional exports and imports or (ii) by assuming that the amount of cross-hauling is proportional to regional sectoral output and then applying a suitable scaling. In the case of CHARM, as detailed later, these *ad hoc* adjustments are replaced by a systematic and well-defined procedure for incorporating the effects of cross-hauling, although it is still possible to refine the estimates of imports and exports by inserting superior data.

In the case of LQs, the most radical innovation has been the development of the FLQ (Flegg's location quotient). This formula was first proposed by Flegg et al. (1995). As refined by Flegg and Webber (1997), it is defined as follows:

$$FLQ_{ij} \equiv CILQ_{ij} \times \lambda^*, \text{ for } i \neq j, \tag{4}$$

$$FLQ_{ij} \equiv SLQ_i \times \lambda^*, \text{ for } i = j. \tag{5}$$

The scalar λ^* is defined as follows:

$$\lambda^* \equiv [\log_2(1 + \text{TRE/TNE})]^{\delta}, \tag{6}$$

where TRE/TNE is the region's relative size, measured as the ratio of total regional to total national employment. It is posited that $0 \leq \delta < 1$; as δ increases, so too does the allowance for interregional imports. $\delta = 0$ represents a special case where $FLQ_{ij} = CILQ_{ij}$. As with other LQ-based formulae, the FLQ is constrained to unity. By giving explicit recognition to a region's relative size, the FLQ should help to address the problem of cross-hauling, which is apt to be more pronounced in smaller regions than in bigger ones (see, for example, Robison and Miller, 1988, table 2).

The SLQ is a well-recognized measure of regional specialization and one can see that the CILQ and FLQ take the specialization of both supplying sector i and purchasing sector j into account, whereas the SLQ only considers the specialization of the supplying sector. The CB method does not allow for specialization explicitly. However, in view of the similarities noted above between the CB and SLQ methods, it may do so implicitly.

As regards regional size, it is evident that the CILQ does not recognize this factor explicitly, whereas it is a key feature of the FLQ. The SLQ does not incorporate regional size explicitly but one can see from the decomposition in equation (2) that the ratio $1/s^r$, where $s^r \equiv \Sigma_i x_i^r / \Sigma_i x_i^n$, plays an implicit role in determining the value of SLQ_i. However, this feature seems counterintuitive: for a given x_i^r / x_i^n, the smaller the region, the greater the value of SLQ_i, and the smaller the allowance for imports from other regions. Furthermore, given the similarities noted above between the SLQ and CB techniques, it seems likely that this counterintuitive property would carry over to any estimates generated by the CB method.

On both theoretical and empirical grounds, the FLQ appears to be the best LQ currently available (Bonfiglio and Chelli, 2008; Flegg et al., 2014; Flegg and Tohmo, 2013b, 2014; Flegg and Webber, 1997, 2000; Kowalewski, 2013; Tohmo, 2004).[1] Its superior empirical performance can be ascribed to the fact that it takes a region's relative size into account and in an appropriate way. The importance of this factor is well articulated by Round (1972, p. 3): 'The smaller the size of the region relative to the nation, the more open the regional economy is likely to be and hence the more likely a significant portion of goods and services will be imported from other regions.'

Since both CHARM and the FLQ attempt to capture cross-hauling, albeit in different ways, which technique should analysts choose? The answer to this question depends on the aims of the analysis and the types of national input–output tables available (Kronenberg, 2012; Flegg and Tohmo, 2013a). CHARM is suitable for examining environmental issues, where the focus is on the overall supply of goods, but it can only be used in situations where imports have been incorporated into the national input–output table (type A tables). Where the focus is on regional output and employment, the FLQ can be used for purposes of regionalization. The FLQ should preferably be applied to national input–output tables that exclude imports (type B tables).[2] However, although both types of national table are available for all European Union members, and also for some other countries, only type A tables are published for China.[3]

To explain why CHARM requires type A tables, consider equation (1). Here the national technical coefficient, a_{ij}, would need to encompass all requirements, including inputs purchased from abroad, otherwise regional intermediate demand, $\sum_j a_{ij} x_j^r$, would be understated. It should be noted that CHARM aims to produce a regional intermediate transactions matrix of type A, i.e. one where the inputs come from all sources, including other regions within the same country as well as foreign countries, whereas the FLQ aims to generate a matrix of type B, i.e. one where the inputs come solely from the given region.

Finally, for completeness, we should mention gravity models, which are relevant here because cross-hauling is intrinsic to such models (cf. Miller and Blair, 2009, p. 365). A simplified regional gravity model might take the following form:

$$\ln c_i^{rs} = \alpha + \beta \ln x_i^r + \gamma \ln d_i^s + \delta \ln t_i^{rs} + \varepsilon_i^{rs}, \quad (7)$$

where c_i^{rs} is the flow of commodity i between regions r and s (representing exports by region r and imports by region s); x_i^r is the output of commodity i in the source region r; d_i^s is the demand for commodity i in the destination region s; t_i^{rs} is the transport cost (proxied by distance) between regions r and s; α, β, γ and δ are parameters to be estimated; and ε_i^{rs} is an error term (cf. Riddington et al., 2006, p. 1075).

Whilst such gravity models are conceptually attractive, the analyst is likely to encounter formidable obstacles in obtaining the data required for a multiregional analysis of this kind. The analytical requirements are also very demanding.[4] For these reasons, non-survey methods such as CHARM and the FLQ possess considerable advantages, particularly where a single region is the focus of interest.

3. THE PROVINCE OF HUBEI

The province of Hubei is located in the central part of China. It produced around 4.0% of China's GDP in 2010 and employed about 2.8% of its urban labour force.[5] 44.3% of Hubei's population resided in urban areas in 2007, a figure that is almost identical to that for China (44.9%).[6] Hubei has a diversified economy. The major agricultural commodities it produces include cotton, rice, wheat and tea, while its key industries include automobiles, iron and steel, chemicals, food and beverages, textiles, machinery and equipment, power generation, shipbuilding and construction, along with high-technology products such as optical electronics and telecommunications. Hubei also has significant mineral and forestry resources.[7]

Hubei is traversed by two great rivers, the Yangtze and the Han, which meet in Wuhan, the provincial capital. The Three Gorges of the Yangtze, which lie to the west of the province, are an important tourist attraction. However, even though hydroelectricity is an important industry in Hubei, the electricity generated is mainly used to supply eastern provinces such as Shanghai, Zhejiang and Jiangsu. Therefore, many coal-fired electricity power stations and heat power plants have been built in several places in Hubei to meet the demand for electricity and heat. Hubei imports coal from Shanxi, Henan and Nei Menggu (Inner Mongolia) to supply these power stations and plants.

Wuhan, which is situated some 1050 km south of Beijing, is one of China's largest cities (the 2010 census recorded a population of 6.4 million in its urban area and 9.8 million in its administrative area). Wuhan is a major transportation thoroughfare and the city is the economic hub of central China. It is a centre of higher education and research.

The published input–output tables for Hubei and China in 2007 have the same forty-two sectors, which greatly simplifies the analysis. Even so, there are some noticeable differences in the extent to which Hubei and China specialize in particular industries. This diversity is captured in the SLQs displayed in Table 1, which were computed using equation (2).

Table 1 near here

Table 1 reveals that Hubei is highly specialized in sectors 1 (agriculture, forestry, animal husbandry and fishing), 5 (mining and selecting of non-metalliferous ore and other minerals), 6 (food manufacturing and tobacco processing), 24 (gas production and supply), 25 (water production and supply) and 39 (education). On the other hand, sectors 2 (coal mining and washing) and 3 (oil and gas mining) are of negligible importance in Hubei.

4. CROSS-HAULING AND CHARM

Regional scientists have tried for several decades to develop a satisfactory way of regionalizing national input–output tables, so that adequate regional tables can be constructed at an acceptable cost, but the existence of cross-hauling has frustrated their efforts (cf. Flegg and Tohmo, 2013b, p. 236). Traditional approaches to regionalization fail to allow for cross-hauling and this failure causes interregional trade to be understated and hence for regional output multipliers to be overstated (*ibid.*). Cross-hauling is an ever-present problem in small regions that do not represent a functional economic area (Robison and Miller, 1988) but it is also a serious concern in larger regions (Kronenberg, 2009). It is more likely to be encountered in densely populated and highly urbanized countries, especially those where commuting across regional boundaries is important (Boomsma and Oosterhaven, 1992, pp. 272–273). Kronenberg identifies the *heterogeneity* of commodities as the main cause of cross-hauling and CHARM represents a novel way of dealing with this problem.

The interregional trade in automobiles between Hubei and other Chinese provinces is a good example of cross-hauling due to product differentiation. For instance, all kinds of Dongfeng-Citroën cars are shipped from Wuhan, where this company's headquarters is situated, to Shanghai and Beijing, where Shanghai-Volkswagen and Beijing-Hyundai have their headquarters, while all types of Shanghai-Volkswagen and Beijing-Hyundai cars are shipped to Wuhan. Tobacco is another good example. Huanghelou is Hubei's sole cigarette brand, while Baisha and Yuxi are the two famous brands of Hunan and Yunan, respectively. There is much interregional trade in cigarettes between Hubei and both Hunan and Yunan.

Although product differentiation may well be the primary cause of cross-hauling, we should also recognize the fact that many of the forty-two sectors discussed earlier represent an aggregation of several distinct commodities, so that cross-hauling is very likely to occur.

Sector 10 (paper, printing, stationery and sporting goods) exemplifies this point. Suppose that Hubei is an importer of sporting goods but an exporter of the other three items; this would create an impression of cross-hauling, which would vanish if sporting goods were reallocated into a separate sector. On the other hand, it should be noted that identical sectoral classifications are used in the tables for China and Hubei, so that there is no additional heterogeneity from this source.

Also germane is a region's relative size. A small region might have few local suppliers of each commodity, whereas more domestic options might exist in a larger region. The range of products on offer from local suppliers in the smaller region might also be more limited. What is more, the transport costs of purchasing from an extraregional supplier would rise as the geographical size of a region increased. For these reasons, one might expect to see more cross-hauling in a comparatively small region than in a comparatively large one.

Let us now examine the mechanics of CHARM and how it differs from the classical CB method. We should note at the outset that both CHARM and the CB method employ national type A tables; this is because they aim to capture the underlying technology of production (Kronenberg, 2012). Such tables include imports from abroad.

The first concept we should examine is the commodity balance for commodity i, b_i, which is identical to *net* exports:

$$b_i \equiv e_i - m_i, \tag{8}$$

where e and m denote exports and imports, respectively. For any region, the value of b_i is estimated by deducting the estimated sum of intermediate and domestic final use of commodity i from an estimate of its output (Kronenberg, 2009, p. 46). In the present example, the output of each of Hubei's forty-two sectors is given in the published tables and thus does not need to be estimated. CHARM and the CB method yield identical values for b_i but different values, in general, for the volume of trade, $e_i + m_i$. This is because CHARM takes cross-hauling explicitly into account. The amount of cross-hauling, q_i, can be calculated via the following equation (*ibid.*, p. 47):

$$q_i = (e_i + m_i) - |(e_i - m_i)|, \tag{9}$$

where $(e_i + m_i)$ is the *volume* and $(e_i - m_i)$ is the *balance* of trade, respectively. Hence cross-hauling will be greater, the larger the volume of trade and the smaller the absolute trade balance. In the CB approach, $q_i = 0$ as $e_i > 0$ and $m_i > 0$ cannot, by assumption, occur simultaneously. By contrast, with CHARM, $q_i > 0$ is possible and, indeed, probable in most cases. For purposes of estimation, Kronenberg postulates that q_i is proportional to the sum of domestic production, x_i, intermediate use, z_i, and domestic final use, f_i, with the factor of proportionality, h_i, being equal to the degree of heterogeneity of commodities, as represented in the following equation (*ibid.*, p. 51):

$$q_i = h_i(x_i + z_i + f_i), \tag{10}$$

where $0 \leq h_i < \infty$. Consequently, $h_i = q_i/(x_i + z_i + f_i)$, where q_i is given by equation (9). Kronenberg assumes that the value of h_i is invariant across regions and depends solely on the characteristics of products; h_i can, therefore, be estimated using national data. (This key assumption is reviewed later in the article.) We would get $h_i = 0$ if $q_i = 0$, which would occur if $e_i = 0$ with $m_i > 0$ or $m_i = 0$ with $e_i > 0$ or $e_i = m_i = 0$.

Table 1 near here

Table 1 displays the values of h_i obtained using Chinese national data.[8] The results exhibit considerable diversity across sectors. Six sectors have $h_i = 0.0000$, indicating the absence of any cross-hauling (indeed, in most cases, any trade). By contrast, manufacturing sectors 19 (communication equipment, computers and other electronic equipment) and 20 (instruments, equipment for cultural industries, and office machinery) show unusually high values of h_i; this suggests that the products produced in these sectors are very heterogeneous and that there is a substantial amount of cross-hauling. h_i is also well above average in manufacturing sectors such as 12 (chemicals), 16 (general and special equipment) and 18 (electrical machinery and equipment). Below-average values of h_i are found especially in service sectors such as 27 (transport and storage), 29 (information transmission, computer services and software) and 31 (hotels and catering services). Sector 34 (leasing and business services) has an unusually high value of h_i for a service sector but this may reflect the possibility that it is less location-specific than most of the other service sectors. Although the results for China look sensible on the whole, there are many sectors where there are large differences between the values of h_i based on national and regional data. Sector 34 is a notable example. This phenomenon is explored in later sections of this article.

5. COMMODITY BALANCES, EXPORTS AND IMPORTS

Before estimates of Hubei's exports and imports can be obtained, it is necessary to estimate the commodity balance (net exports) for each commodity. The following formula was used:

$$\hat{b}_i^r = x_i^r - (\hat{z}_i^r + \hat{f}_i^r + \hat{g}_i^r), \quad (11)$$

where $\hat{b}_i^r$ is estimated net exports of commodity i, x_i^r is regional output of this commodity, as shown in the official statistics, $\hat{z}_i^r$ is the estimated sum of regional intermediate use, $\hat{f}_i^r$ is the estimated regional final use and $\hat{g}_i^r$ is the estimated residual error.[9]

$\hat{z}_i^r$ was calculated using the formula:

$$\hat{z}_i^r = \sum_j \hat{z}_{ij}^r = \sum_j (a_{ij}^n \times x_j^r), \quad (12)$$

where a_{ij}^n is the national technical coefficient (number of units of commodity i required to produce one unit of gross output of national industry j) and $\hat{z}_{ij}^r$ is the estimated value of intermediate inputs of commodity i required by industry j in Hubei. It was assumed that Hubei and China shared the same technology. The values of $\hat{f}_i^r$ and $\hat{g}_i^r$ were calculated by scaling down the respective national values, using the following formulae:

$$\hat{f}_i^r = \frac{x_i^r}{x_i^n} \times f_i^n, \tag{13}$$

$$\hat{g}_i^r = \frac{x_i^r}{x_i^n} \times g_i^n. \tag{14}$$

This proportional scaling is a very common approach; in the case of private consumption, it can be justified by the approximately proportional relationship that is likely to exist between consumers' expenditure and output.[10]

Equation (11) is all that is needed under the CB approach, which does not yield separate estimates of exports and imports, and presumes that the volume of trade is equal to the absolute trade balance. However, with CHARM, some further calculations are required in order to take cross-hauling into account (cf. Kronenberg, 2009, p. 50). The first step is to rearrange equation (9) to get an expression for the volume of trade, v_i:

$$v_i \equiv e_i + m_i = |b_i| + q_i, \tag{15}$$

where b_i (net exports) was estimated via equation (11) and q_i (cross-hauling) via the equation:

$$\hat{q}_i^r = h_i(x_i^r + \hat{z}_i^r + \hat{f}_i^r + \hat{g}_i^r), \tag{16}$$

where h_i is the measure of heterogeneity of commodities (based on national data). Finally, regional exports and imports were computed from the expressions:

$$e_i = ½(v_i + b_i), \tag{17}$$

$$m_i = ½(v_i - b_i), \tag{18}$$

where estimates of b_i and v_i were obtained from equations (11) and (15). We are now able to calculate Hubei's balance and volume of trade, as well as its imports and exports separately.

6. ESTIMATING HUBEI'S IMPORTS AND EXPORTS

Table 2 near here

Table 2 highlights the differences between CHARM and its predecessor, the CB method. A key point is that, with the CB method, a positive trade balance (where regional output of a commodity exceeds the sum of regional intermediate and final demand) generates an equivalent amount of regional exports but no imports. Conversely, a negative trade balance (where regional output of a commodity falls short of the sum of regional intermediate and final demand) yields an equivalent amount of regional imports but no exports. Cross-hauling is presumed not to occur with the CB approach, whereas CHARM takes this common characteristic of regional trade explicitly into account, which is why it yields a higher overall volume of both exports and imports. This outcome, which is in line with the findings of Flegg and Tohmo (2013b) for Finland, can be verified from the last row of Table 2. The figures there show that exports are 32% higher and imports are 50% higher with CHARM than with the CB method. The size of these differences is striking.

However, what is most surprising about the results in Table 2 is that CHARM also yields much higher figures for exports and imports than those recorded in the official statistics (61% higher for exports and 23% higher for imports). To shed some light on the possible causes of these unexpected results, it is fruitful to examine the outcomes for selected individual sectors.

Table 2 reveals some striking disparities between the estimates for manufacturing imports given by CHARM and the CB method. For instance, CHARM yields far higher imports for sectors such as 12 (chemicals), 16 (general and special equipment) and 19 (communication equipment, computers and other electronic equipment). These are all sectors with values of h_i for China, hereafter h_i^n, that are well above average (see Table 1), indicating a high degree of heterogeneity of products. For the services part of Hubei's economy, comprising sectors 27 to 42, sector 34 (leasing and business services) is the only one where CHARM gives a markedly higher figure for regional imports. This outcome can be linked to a value of h_i^n that is well above average for the service sectors. It is also worth noting that the CB approach suggests that twenty-five of the forty-two sectors did not import any of their inputs, whereas CHARM finds only five such cases.

In many instances, CHARM's estimates of imported manufactured goods far exceed those recorded in the official figures, although the huge shortfall in sector 6 (food manufacturing and tobacco processing) is a striking exception to this pattern. A less extreme error of this kind occurs in sector 17 (transportation equipment). Outside of manufacturing, it is noticeable how CHARM yields an unrealistically low figure for the imports of sector 1 (agriculture, forestry, animal husbandry and fishing). In the case of services, the only anomalous sector is 34 (leasing and business services): here CHARM gives a much higher figure for regional imports than that recorded in the official statistics.

To elucidate the discrepancies between CHARM's estimates of Hubei's imports and the official figures, it is helpful to substitute equation (15) into equation (18), so that:

$$m_i = ½(|b_i| + q_i - b_i), \tag{19}$$

which gives $m_i = ½q_i$ for $b_i > 0$ and $m_i = ½q_i + |b_i|$ for $b_i < 0$, where $b_i \equiv e_i - m_i$.

Now consider the anomalous sector 1 (agriculture, forestry, animal husbandry and fishing) mentioned above, where $b_i > 0$. The equation $m_i = ½q_i$ indicates that CHARM's unrealistically low figure for imports must be the result of a substantial understatement of the amount of cross-hauling, q_i. Equation (16) reveals that this outcome could be due to the use of too small a value for h_i or, ignoring the residual error, to an understatement of the sum of regional intermediate and final use, $z_i^r + f_i^r$, or to both sources of error. To investigate the first possibility, h_i was recomputed using the official data for Hubei. From Table 1, one can see that its value for sector 1 rises dramatically, from $h_i^n = 0.0134$ to $h_i^r = 0.1603$, when regional rather than national data are used.

Table 3 near here

Table 3 shows that the use of a more realistic value of h_i for sector 1 eliminates all but 4,116 million yuan (11.2%) of the shortfall between CHARM's estimate of imports and the official figure. A similar outcome occurs in sector 6 (food manufacturing and tobacco processing): when a more appropriate figure for h_i is used, namely $h_i^r = 0.1723$ rather than $h_i^n = 0.0380$, the gap between the official figure for imports and CHARM's estimate shrinks to 2,584 million yuan (8.6%). If we ignore the residual error, these remaining shortfalls can be ascribed to errors in estimating Hubei's intermediate and final demand.

Sector 19 (communication equipment, computers and other electronic equipment) is an interesting case: here CHARM's estimate of imports is way above the official figure. The explanation of this discrepancy is rather complex: since $b_i < 0$, $m_i = ½q_i + |b_i|$, so there are two possible sources of error. As regards cross-hauling, q_i, Table 1 reveals that $h_i^n = 0.4217$, whereas $h_i^r = 0.1571$. As expected, Table 3 shows that using this lower regional figure for h_i has the effect of compressing the gap between CHARM's estimate of imports and the official figure. However, in this instance, the size of the absolute trade balance, $|b_i|$, also needs to be considered. By using the official figure from Table 2, b_i = –3,915, instead of CHARM's estimate, –15,743, the gap between the official figure for imports and CHARM's estimate is reduced to only 929 million yuan (8.7%).

Sector 12 (chemicals) is another example of where CHARM's estimate of imports is way above the official figure. Like sector 19, sector 12 has $b_i < 0$, so that $m_i = ½q_i + |b_i|$. However, in this instance, there is relatively little difference between the estimates of h_i derived from national and regional data ($h_i^n = 0.1150$; $h_i^r = 0.0948$), so that the error in the value of h_i has minimal overall impact. In fact, CHARM's overstatement of imports is almost entirely due to the use of an erroneous value for b_i of –34,441, which is absolutely much larger than the official value of –11,561. There are some other sectors where CHARM yields unsatisfactory figures for imports but all of these discrepancies can be explained by the use of inaccurate values for either b_i or q_i or both.

The data for regional exports are also presented in Table 2. Once again, sectors 12 (chemicals), 16 (general and special equipment) and 19 (communication equipment, computers and other electronic equipment) highlight the importance of recognizing heterogeneity and hence cross-hauling: whereas CHARM generates a substantial volume of exports, the CB approach suggests that these three sectors did not export any of their output. Indeed, this approach suggests that seventeen of the forty-two sectors did not export. This presumption is less extreme than the finding that twenty-five of them did not import.

It is interesting that sector 6 (food manufacturing and tobacco processing), which posed a serious problem as regards imports, is unproblematic in terms of exports: both CHARM and the CB method produce sensible estimates of exports for this sector. On the other hand, both methods fail to account for the large volume of exports recorded in the official statistics for sector 23 (electric power, heat power production and supply). Furthermore, worryingly large discrepancies between the official and estimated figures for exports also occur in sectors 26 (construction), 30 (wholesale and retail trade), 33 (real estate), 39 (education) and 42 (public management and social organization). These anomalies, which represent extremely large overstatements of exports by both methods, are especially puzzling as they occur in the construction and service sectors, where heterogeneity and hence cross-hauling are unlikely to be important in most cases. Indeed, Table 1 shows that the values of h_i^n for these five sectors are either zero or close to zero. Therefore, the overstatement of exports must essentially be due to an overstatement of the trade balance, b_i. When this error is rectified, Table 3 shows that CHARM generates sensible figures for the exports of these five sectors.

From the above discussion, it is obvious that CHARM's estimates of exports and imports for individual sectors need to be treated with considerable caution. The figures for exports of services are especially unreliable. The primary cause of these errors is the difficulty of getting reliable regional figures for net exports and the degree of heterogeneity of products.

Possible ways round this problem are explored in the penultimate section of the article.

7. ESTIMATING SUPPLY MULTIPLIERS FOR HUBEI

A multiplier is an invaluable tool for evaluating the impact of fluctuations in the demand for a particular regional sector's product. Indeed, regional analysts are apt to be more concerned with getting satisfactory estimates of multipliers than they are with estimating the volume of exports and imports. In this study, *supply* rather than *output* multipliers have been calculated (Kronenberg, 2012). Supply multipliers measure the impact of changes in final demand on the total supply of commodities rather than on regional output. They are, therefore, useful in environmental assessments, where the focus is on the total supply of a pollutant rather than on where it was produced. A good example here is the coal imported by Hubei to supply its coal-fired power stations and power plants, as mentioned earlier.

The supply multipliers were computed as follows. First, the supply of each industry j was calculated by summing the regional output of j, x_j, and the imports of this product, m_j. Secondly, a set of supply-based regional input coefficients was defined as:

$$r_{ij}^s = z_{ij}/(x_j + m_j), \tag{20}$$

where z_{ij} is the total value of intermediate inputs purchased by industry j from sector i, inclusive of goods sourced from within Hubei, from other provinces or from abroad. The coefficient matrix corresponding to equation (20) can be written as $\mathbf{R^s} = [r_{ij}^s]$. Thirdly, the Leontief inverse of $\mathbf{R^s}$ was derived. This can be expressed as $\mathbf{L^s} = [b_{ij}^s]$. Lastly, each column of $\mathbf{L^s}$ was summed to obtain a figure for the sectoral supply multiplier, k_j:

$$k_j = \sum_i b_{ij}^s. \tag{21}$$

This process was repeated for the CB method, CHARM and the official data. The results are displayed in Table 4.

Table 4 near here

Table 4 shows that the official data yield a mean supply multiplier of 1.919. This figure suggests that a rise in the final demand for Hubei's industries of one million yuan would raise the total supply of commodities (including products imported from other provinces or from abroad) by 1.919 million yuan on average. CHARM indicates a somewhat higher average rise of 2.078 million yuan, whereas the CB method signals a rise of 2.218 million yuan.

From Table 4, one can see that the CB method invariably produces bigger supply multipliers than CHARM. On average, the value of k_j is 2.078 for CHARM but 2.218 for the CB method. This outcome can easily be explained in terms of equation (20): the two approaches use identical values for z_{ij} and x_j but different values for m_j. The value of m_j is higher for CHARM because it takes heterogeneity of products and hence cross-hauling into account, whereas the CB method does not. Consequently, the input coefficients and hence supply multipliers from CHARM are lower than those from the CB method.[11]

Table 4 reveals that the gap between the estimated multipliers from CHARM and the CB method varies markedly across sectors. This gap is negligible for sectors producing relatively homogeneous products, where cross-hauling is unlikely to be significant. A good example is sector 15 (fabricated metal products). By contrast, big gaps arise for sectors such as 19 (communication equipment, computers and other electronic equipment) and 20 (instruments, equipment for cultural industries, and office machinery), which have very high values of h_i and hence exhibit much cross-hauling, especially at the national level (see Table 1).

It is also worth noting in Table 4 that sectors 2 (coal mining and washing), 3 (oil and gas mining) and 22 (waste and scrap) have multipliers close to the minimum of $k_j = 1$. This is true for both methods. These unusual results arise because these sectors have minimal presence in Hubei's economy: each produces a mere 0.1% of the province's total output (see Table 1). Consequently, intermediate transactions are negligible and a very high proportion of the supply in these sectors is imported from other regions.[12]

The finding that the official data give a somewhat lower mean multiplier than CHARM can once more be explained in terms of equation (20): the multipliers from CHARM and those derived from the official statistics for Hubei use identical values for x_j but different values, in general, for both z_{ij} and m_j. As regards z_{ij}, it is helpful to examine the ratio $\sum_i z_{ij} / x_j$, which represents the degree of intermediation. In the case of CHARM, the z_{ij} were calculated using the national technical coefficients and hence reflect the national technology, whereas the official tables for Hubei reflect technology specific to this province. In fact, for thirty-four out of forty-two sectors, CHARM gives a higher value for $\sum_i z_{ij} / x_j$. On average, this ratio is 0.619 for CHARM but 0.553 for the official data. This disparity is a key reason why the multipliers from CHARM exceed those based on the official data (see Table 4).

To assess the impact of technological differences, the multipliers were recalculated by using the official data for intermediate inputs in place of estimates derived by multiplying the known output of each sector by the corresponding national technical coefficient. This substitution affected the multipliers directly via the change in z_{ij} in equation (20) and caused the mean multiplier to fall from 2.078 to 1.860. This reduction reflects the fact that Hubei's industries are typically more efficient in terms of their use of intermediate inputs than those in China as a whole.

However, with CHARM, the value of z_{ij} has an indirect impact on the size of the supply multipliers via its effect on m_j in equation (20). Imports are affected because a change in intermediate transactions alters the estimated trade balance, $\hat{b}_i^r$ in equation (11), and the estimate of cross-hauling, $\hat{q}_i^r$ in equation (16). When these indirect effects on imports were taken into account, the mean multiplier rose from 1.860 to 1.923. This rise in the mean value of k_j is a consequence of the fall in the estimated volume of imports generated by CHARM, which has the effect of increasing the size of the input coefficients in equation (20). Indeed, it was noted earlier that CHARM's original estimate of Hubei's total imports exceeded the official figure by 23%. The use of the official transactions data clearly goes a long way towards eliminating this overstatement.

Finally, we need to explore the effects of replacing the national figures for the degree of heterogeneity of commodities with region-specific data (see Table 1). The data for Hubei have a slightly higher mean than the national data (0.0696 versus 0.0606). Using h_i^r rather than h_i^n in equation (16) to estimate cross-hauling produces marginally higher imports and hence supply for a typical sector and this, in turn, slightly lowers the mean multiplier from 1.923 to 1.904. We don't get the exact official mean of 1.919 as we are still estimating regional final demand and the residual error, which affects the value of m_j in equation (20).[13] The adjustment for heterogeneity makes little difference, on average, because eighteen sectors have $h_i^n > h_i^r$, eighteen have the opposite and four have $h_i^n = h_i^r$. Nevertheless, this unremarkable overall outcome masks some fairly large changes in the multipliers for several sectors, which reflect the marked disparities in the values of h_i^n and h_i^r for these sectors (see Table 1). Sector 20 (instruments, equipment for cultural industries, and office machinery) is a case in point: $h_i^n = 0.6915$ gives $k_j = 1.698$, whereas $h_i^r = 0.2349$ yields $k_j = 1.913$.

8. ENHANCING CHARM'S PERFORMANCE

The disappointing results from CHARM indicate that we should explore possible ways of enhancing its performance. The earlier discussion highlighted two key weaknesses in this approach: (i) the use of national technical coefficients to represent regional technology and (ii) the use of national data to measure the heterogeneity of commodities.

The multiplier analysis suggested that the main source of error in the estimates of supply multipliers was that the national technical coefficients did not accurately measure the technical requirements of Hubei's industries, leading to inaccurate estimates of intermediate demand. Productivity in Hubei generally exceeds that in China as a whole, which means that its technical coefficients tend to be smaller than the corresponding national ones. This means, of course, that the proportion of value added – primarily labour costs and profits – tends to be higher in Hubei than in China as a whole. This problem can be addressed, in principle at least, by using Round's 'fabrication' factor (Round, 1972, p. 6).

Round's approach can be implemented via the following formula:

$$a_{ij}^{r} = \frac{1-(w_j^r/x_j^r)}{1-(w_j^n/x_j^n)} a_{ij}^{n}, \tag{22}$$

where w denotes value added, x denotes gross output, and r refers to the region being examined (cf. Miller and Blair, 2009, pp. 356–357). To illustrate, consider sector 20, for which $w_j^r/x_j^r = 0.3055$ but $w_j^n/x_j^n = 0.2116$. Thus $a_{ij}^r = 0.881 \times a_{ij}^n$, so that the national technical coefficients in column 20 of Hubei's matrix would need to be scaled down by a common factor of 0.881, i.e. reduced by 11.9%, to reflect the more economical use of intermediate inputs by sector 20 in Hubei relative to China as a whole. In equation (12), a_{ij}^n would need to be replaced by a_{ij}^r. To take another example, consider sector 29, for which $w_j^r/x_j^r = 0.6961$ but $w_j^n/x_j^n = 0.6003$. Here $a_{ij}^r = 0.760 \times a_{ij}^n$, so that the a_{ij}^n in column 29 would need to be scaled down by a more severe 24.0%. Such adjustments are easy to implement but they presuppose that the analyst is aware of which regional industries diverge significantly from the national value-added ratios and by how much.[14]

Another way of enhancing CHARM's performance would be to pursue a hybrid approach, which aims 'to strike a balance between the accuracy of [a regional input–output] table and the cost of constructing it' (Kronenberg, 2009, p. 52). Indeed, Kronenberg advocates the use of just such a strategy; more specifically, he recommends making judicious use of superior data from official sources and partial surveys. For instance, analysts might be able to obtain disaggregated data on regional consumption by households, which could be used to improve the estimates of final demand. Also, partial surveys could be carried out of key sectors and important cells in the regional input–output table. Furthermore, Lahr (1993) emphasizes the importance of obtaining superior data for households and for establishments in resource-based and 'miscellaneous' sectors. He singles out agriculture and the extractive industries as cases where a divergence between regional and national technology is very likely to occur.

The other major source of error in applications of CHARM concerns the use of national data to measure the degree of heterogeneity of commodities. Kronenberg (2009, p. 51) justifies the assumption that $h_i^n = h_i^r$ on the grounds that 'the heterogeneity of commodity *i* is the same in the region as in the nation', which he says is reasonable 'because product heterogeneity is a characteristic of the commodity, not of a specific geographical location.' Whilst it may well be reasonable to assume that regional and national products exhibit the same degree of heterogeneity, what is more contentious is whether the mix of products in regional and national sectors is sufficiently similar to warrant the assumption that $h_i^n = h_i^r$.

In considering possible adjustments, analysts would need to scrutinize each national sector and compare its composition with the assumed regional configuration. The values of h_i could then be adjusted manually if deemed necessary. For instance, where an analyst concluded that there was less differentiation of products (more specialization) at the regional than at the national level for a given sector, the value of h_i could be adjusted downwards. As with any *ad hoc* adjustment, informed judgements would be required.

9. CONCLUSION

This article has used data for the Chinese province of Hubei to assess the performance of Kronenberg's CHARM, a new method designed to take explicit account of the widespread practice of cross-hauling (the simultaneous exporting and importing of a given commodity) when constructing regional input–output tables. By adjusting the Chinese national tables, CHARM was used to simulate the input–output structure of Hubei. The results were then compared with the official data for Hubei, as well as with figures obtained by pursuing the classical commodity balance (CB) approach.[15]

At the outset, Kronenberg's procedure was employed to estimate the degree of heterogeneity for forty-two separate commodities, using Chinese national data. This application seemed, at first sight, to generate satisfactory results. The estimates of heterogeneity were then used to make adjustments for cross-hauling and to generate a set of estimates for Hubei of the volume of exports, the volume of imports, and the volume of trade. Unfortunately, in many cases, these estimates of exports and imports were unrealistic. Furthermore, for most sectors, CHARM generated much higher figures for the volume of trade than those recorded in the official input–output table for Hubei. These disappointing results can be attributed to the difficulty, in this instance, of obtaining adequate estimates of both intermediate use and the degree of heterogeneity of commodities.

Although CHARM was found wanting in terms of measuring Hubei's volume and pattern of trade, its estimates of supply multipliers were generally more realistic. These multipliers suggested that, on average, a rise in the final demand for Hubei's industries of one million yuan would raise the total supply of commodities (including products imported from other provinces or from abroad) by 2.078 million yuan. By contrast, the CB method signalled a rise of 2.218 million yuan. This higher figure can be explained by the fact that the CB method does not take heterogeneity and hence cross-hauling into account.

Given the disappointing results obtained from CHARM, we explored various ways in which its performance might be enhanced and identified three in particular. The first was to use Round's 'fabrication' factor to adjust for any known divergence between regional and national technology. Secondly, a hybrid approach could be pursued, with judicious use being made of superior data gleaned from official sources and from partial surveys of key regional sectors and important cells in the regional input–output table. Thirdly, the values of the national measure of heterogeneity of products could be adjusted to allow for any known differences between the sectoral mix of products at the regional and national levels.

The results presented here for Hubei differ markedly from those obtained by Flegg and Tohmo (2013b) in their case study of the Finnish province of Uusimaa: whereas CHARM produced reasonable estimates of the volume and pattern of trade in Uusimaa, this was certainly not true for Hubei. A key reason for this dissimilarity is probably the fact that Uusimaa is a relatively large province, which produced 34.6% of Finland's national output in 2002, and accounted for 31.4% of total employment, whereas Hubei produced around 4% of China's GDP in 2010 and employed about 2.8% of its urban labour force. A region's relative size is liable to affect the results via differences in both technology and the heterogeneity of products. Here it is worth noting that Kronenberg and Többen (2013) found that CHARM produced generally satisfactory results for the German federal state of Baden–Württemberg, a relatively large region that generated some 14% of Germany's national output in 1991.

Regional technology is more likely to be akin to national technology, the larger the relative size of a region since a greater proportion of national production will take place within the region. Obviously, regional and national technology will converge as regional size approaches the maximum. A divergence between regional and national technical coefficients was very evident in the case of Hubei and this impaired the estimates of commodity balances and hence imports, exports and supply multipliers.

With Kronenberg's procedure, the degree of heterogeneity of commodities is estimated using national data and these estimates play a key role in calculating the amount of cross-hauling. However, it seems likely that the degree of heterogeneity present in international trade would differ from that in interregional trade, although this difference would tend to decrease as the relative size of a region increased. For instance, in the computer industry, the range of products traded internationally by China might exceed the range of products traded with other Chinese regions by Hubei. Furthermore, the sheer geographical size of China, when compared with more compact countries such as Finland and Germany, is likely to pose problems in any simulation of regional trade.

There are, therefore, good reasons to suppose that CHARM would tend to perform better in relatively large regions such as Uusimaa than in relatively small ones such as Hubei. This finding serves to emphasize the importance, especially in smaller regions, of adjusting for differences in technology and heterogeneity. As with any nonsurvey technique, CHARM can only be expected to produce an initial set of results, which should then be reviewed by the analyst and suitable adjustments made.

Footnotes

1. Riddington et al. (2006) cast doubt on the usefulness of the FLQ. For a comment on their study, see Flegg and Tohmo (2013b, pp. 707−708).
2. Although it is possible, in principle, to apply LQs to national technical coefficients, i.e. coefficients that include foreign imports, Flegg and Webber (1997, p. 801) argue that it would be preferable to use national coefficients that exclude such imports. Their reasoning is that the a_{ij} 'reflect commodities produced by both domestic and foreign workers and they thus provide a questionable theoretical basis for the application of LQs derived from domestic employment' (*ibid.*). They go on to say that 'greater import penetration – whether from abroad or from other regions – would be reflected in lower regional employment and hence in smaller LQs' (*ibid.*). These smaller LQs would, in turn, generate a bigger allowance for imports from other regions.
3. This taxonomy of tables follows Kronenberg (2012) and the United Nations (1973).
4. Riddington et al. (2006) used a gravity modelling approach to construct an input−output model

for a Scottish region with some 2.3% of overall Scottish employment. Their work was greatly assisted by the existence of a detailed Scottish regional economic accounting model, which offered detailed regional data for forty local areas. Nevertheless, their painstaking work illustrates the complexity of producing a regional model in this way.

5. Source: National Bureau of Statistics of China (2011a).

6. Source: National Bureau of Statistics of China (2009).

7. For more detail on Hubei's economy, see Hubei Bureau of Statistics (2011).

8. In the calculations, the formula was modified to $h_i = q_i/(x_i + z_i + f_i + g_i)$, where g_i is the residual error, which arises because national output is unequal to the sum of domestic intermediate and final demand plus net exports or, symbolically, $x_i \neq z_i + f_i + (e_i - m_i)$. To illustrate, consider sector 12 (chemicals), for which q_i = 1,447,584, x_i = 6,199,809, z_i = 6,156,694, f_i = 284,330 and g_i = −54,490, so that h_i = 0.1150.

9. For Hubei in 2007, the official data show an overall residual error equal to 1.2% of output.

10. There is a potential problem where a product is consumed but not produced in a region. So long as the necessary data are available, it would be preferable to use the ratio of regional to national total final consumption of households as the scaling factor. In this case, one would need to assume that the regional and national structures of consumption were similar. If regional sectoral output data are unavailable, one could follow Kronenberg (2009) in using employment as a proxy. Other possible scaling factors are labour income and value added. For more discussion of possible approaches to scaling, see Jackson (1998, pp. 231–234). More generally, in the case of Hubei, Kronenberg's assumption of a proportional relationship between regional and national total domestic final use appears justified by the fact that the official data for Hubei exhibit a fairly close relationship between sectoral total domestic final use and output (r = 0.80, significant at 1%). Moreover, this relationship appears to be a proportional one (the intercept is not significantly different from zero, p = 0.285). Therefore, even though one might query Kronenberg's assumption of proportionality on *a priori* grounds, any inaccuracy in this assumption is unlikely to have a material bearing upon the outcomes of the modelling.

11. CHARM and the CB method would produce identical output multipliers because the term m_j in equation (20) would not be present.

12. According to the official statistics, the ratio $\sum_i z_{ij}/(x_j + m_j)$ equalled 0.078, 0.054 and 0.139, respectively, for sectors 2, 3 and 22. CHARM gave figures of 0.069, 0.026 and 0.049. Hence it is unsurprising that the multipliers for these sectors are very low.

13. The need to estimate final demand and the residual error had little impact on the size of the estimated supply multipliers for most sectors. However, sector 21 (arts, crafts and other manufacturing) was an exception: here the multiplier calculated from official data was 2.596, whereas the value from CHARM was only 2.147.

14. Data to inform such assessments can be gleaned from many sources. For instance, in Germany, value added is reported annually for the federal states disaggregated into 16 sectors. In Finland, regional accounts are published annually and are a source of value-added data. In the case of the USA, Lahr (2001, p. 172) remarks that 'The US Bureau of Economic Analysis, which releases the official US I-O tables, produces a series on value added for states, albeit at a rather aggregated level both geographically and sectorally.'

15. It should be noted that the official statistics used in this evaluation of CHARM are bound to contain errors, yet their extent is unfortunately impossible to ascertain with any precision. Nevertheless, in the authors' considered opinion, the official figures for Hubei's exports and imports appear to be questionable in the following instances:
    Sector 1: the recorded figure for net exports of 1,857 million yuan looks rather low.
    Sector 17: there should arguably be a positive rather than a negative trade balance.
    Sector 24: there should arguably be a negative rather than a positive trade balance.
    Sector 28: there should arguably be a positive rather than a negative trade balance.

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TABLE 1. Sectoral shares of output and heterogeneity of products in 2007: Province of Hubei and China.

Sector	Description	Share of output		SLQ_i	Degree of heterogeneity (h_i)	
		Hubei	China		China	Hubei
1	Agriculture, forestry, animal husbandry and fishing	0.104	0.060	1.740	0.0134	0.1603
2	Coal mining and washing	0.001	0.012	0.096	0.0200	0.0008
3	Oil and gas mining	0.001	0.012	0.068	0.0141	0.0120
4	Metal mining and selecting	0.004	0.008	0.534	0.0101	0.5963
5	Mining and selecting of non-metalliferous ore and other minerals	0.008	0.005	1.789	0.0383	0.0682
6	Food manufacturing and tobacco processing	0.081	0.051	1.580	0.0380	0.1723
7	Textile industry	0.036	0.031	1.168	0.0381	0.0908
8	Manufacturing of textile clothing, shoes, hats, leather and down	0.024	0.022	1.102	0.0392	0.0136
9	Wood processing and furniture manufacturing	0.011	0.013	0.798	0.0273	0.0377
10	Paper, printing, stationery and sporting goods	0.018	0.018	0.973	0.0583	0.0177
11	Oil processing, coking and nuclear fuel processing	0.013	0.026	0.488	0.0359	0.0055
12	Chemical industry	0.057	0.076	0.755	0.1150	0.0948
13	Manufacturing of non-metallic minerals	0.033	0.028	1.170	0.0170	0.0594
14	Metal smelting and press processing	0.045	0.075	0.600	0.0712	0.1452
15	Fabricated metal products	0.024	0.022	1.098	0.0361	0.0382

16	Manufacturing of general and special equipment	0.035	0.048	0.730	0.1429	0.1411
17	Manufacturing of transportation equipment	0.043	0.040	1.063	0.0915	0.2078
18	Manufacturing of electrical machinery and equipment	0.013	0.033	0.391	0.1349	0.0870
19	Manufacturing of communication equipment, computers and other electronic equipment	0.019	0.050	0.369	0.4217	0.1571
20	Manufacturing of instruments, equipment for cultural industries, and office machinery	0.004	0.006	0.692	0.6195	0.2349
21	Arts, crafts and other manufacturing	0.005	0.008	0.650	0.0393	0.0126
22	Waste and scrap	0.001	0.005	0.237	0.0063	0.0282
23	Electric power, heat power production and supply	0.030	0.038	0.779	0.0006	0.1537
24	Gas production and supply	0.004	0.001	3.237	0.0000	0.0023
25	Water production and supply	0.003	0.001	2.322	0.0000	0.0000
26	Construction	0.089	0.077	1.157	0.0035	0.0000
27	Transport and storage	0.045	0.039	1.174	0.0352	0.0645
28	Post	0.001	0.001	1.380	0.0560	0.0227
29	Information transmission, computer services and software	0.013	0.012	1.071	0.0399	0.0480
30	Wholesale and retail trade	0.046	0.035	1.314	0.0000	0.0548
31	Hotels and catering services	0.025	0.018	1.359	0.0356	0.0128
32	Financial intermediation	0.023	0.024	0.981	0.0044	0.0236

33	Real estate	0.025	0.018	1.366	0.0000	0.0000
34	Leasing and business services	0.011	0.014	0.754	0.2118	0.0245
35	Research and development	0.002	0.002	1.118	0.0155	0.0230
36	Comprehensive technology services	0.004	0.005	0.783	0.0000	0.0000
37	Management of water conservancy, environment and public facilities	0.003	0.003	1.288	0.0000	0.0000
38	Services to households and other services	0.013	0.011	1.234	0.0232	0.0000
39	Education	0.031	0.016	1.912	0.0020	0.0118
40	Health, social security and social welfare	0.017	0.014	1.249	0.0018	0.0000
41	Culture, sports and entertainment	0.006	0.004	1.360	0.0860	0.0025
42	Public management and social organization	0.030	0.019	1.553	0.0027	0.0000
	Sum or mean	1.000	1.000		0.0606	0.0696

Source: Authors' calculations using data from the official input–output tables for China and Hubei in 2007 (National Bureau of Statistics of China, 2011b).

TABLE 2. Estimation of Hubei trade (millions of yuan) in 2007.

Sector	CHARM				CB approach				Official statistics				
	Exports	Imports	Trade balance	Trade volume	Exports	Imports	Trade balance	Trade volume	Exports	Imports	Trade balance	Trade volume	Output
1	55938	2731	53207	58669	53207	0	53207	53207	38654	36797	1857	75451	230478
2	220	17205	−16985	17424	0	16985	−16985	16985	8	16287	−16279	16295	2520
3	198	24776	−24578	24973	0	24578	−24578	24578	111	15134	−15023	15245	1745
4	131	8193	−8062	8324	0	8062	−8062	8062	7164	13395	−6230	20559	8901
5	7634	580	7054	8214	7054	0	7054	7054	1790	1255	535	3045	18667
6	46355	6029	40326	52383	40326	0	40326	40326	40245	29921	10325	70166	178833
7	28551	2539	26012	31090	26012	0	26012	26012	21545	6555	14990	28099	79711
8	19090	1774	17315	20864	17315	0	17315	17315	8460	683	7777	9143	53953
9	736	647	89	1383	89	0	89	89	913	1892	−978	2805	23761
10	2513	2288	225	4801	225	0	225	225	743	8806	−8063	9549	39367
11	1483	28522	−27039	30005	0	27039	−27039	27039	204	19140	−18935	19344	27835
12	16554	50965	−34411	67518	0	34411	−34411	34411	12557	24118	−11561	36675	126726
13	9820	1152	8669	10972	8669	0	8669	8669	11501	4069	7432	15569	72267
14	7924	32013	−24089	39937	0	24089	−24089	24089	17098	14198	2900	31296	99239
15	19165	1581	17584	20746	17584	0	17584	17584	12873	1799	11074	14672	52654
16	12646	33332	−20685	45978	0	20685	−20685	20685	11236	14201	−2966	25437	78141
17	11811	8536	3275	20347	3275	0	3275	3275	20013	22647	−2635	42660	94972
18	5568	30714	−25145	36282	0	25145	−25145	25145	2581	4510	−1929	7090	28697
19	20695	36438	−15743	57133	0	15743	−15743	15743	6780	10695	−3915	17475	41205
20	7154	11963	−4809	19117	0	4809	−4809	4809	2508	5571	−3063	8078	9143

21	470	2606	−2136	3077	0	2136	−2136	2136	604	134	470	738	10883
22	43	8162	−8118	8205	0	8118	−8118	8118	404	356	48	760	2799
23	40	7046	−7006	7086	0	7006	−7006	7006	27526	8777	18749	36303	66487
24	6598	0	6598	6598	6598	0	6598	6598	2742	20	2722	2761	9719
25	4057	0	4057	4057	4057	0	4057	4057	0	0	0	0	7416
26	26521	649	25872	27170	25872	0	25872	25872	0	0	0	0	196670
27	22415	3207	19209	25622	19209	0	19209	19209	20636	6027	14610	26663	100810
28	542	142	400	684	400	0	400	400	66	418	−352	484	2733
29	2428	1135	1294	3563	1294	0	1294	1294	1410	1995	−585	3405	29105
30	35899	0	35899	35899	35899	0	35899	35899	15961	5336	10625	21297	102634
31	13693	1727	11966	15420	11966	0	11966	11966	4446	676	3770	5122	54532
32	234	2314	−2081	2548	0	2081	−2081	2081	1386	1220	166	2606	51771
33	13498	0	13498	13498	13498	0	13498	13498	0	0	0	0	54679
34	5915	13615	−7700	19530	0	7700	−7700	7700	1477	580	897	2057	24080
35	70	759	−689	829	0	689	−689	689	114	1646	−1532	1759	4176
36	0	2481	−2481	2481	0	2481	−2481	2481	0	2702	−2702	2702	9329
37	1229	0	1229	1229	1229	0	1229	1229	0	0	0	0	7528
38	4663	633	4030	5296	4030	0	4030	4030	0	0	0	0	29263
39	31031	103	30928	31134	30928	0	30928	30928	3003	788	2215	3791	67693
40	7624	61	7562	7685	7562	0	7562	7562	0	0	0	0	37645
41	3563	1013	2550	4575	2550	0	2550	2550	32	129	−97	162	13048
42	23741	145	23596	23886	23596	0	23596	23596	0	0	0	0	66554
Sum	478459	347775	130685	826234	362444	231759	130685	594203	296790	282474	14316	579264	2218368

Source: See Table 1.

TABLE 3. The impact on the estimates from CHARM of using official Hubei data (millions of yuan) in 2007.

Sector	Imports						Exports					
	Original estimates of imports	Error	Estimates using official h_i	Error	Estimates using official h_i and b_i	Official data for imports	Original estimates of exports	Error	Estimates using official h_i	Error	Estimates using official h_i and b_i	Official data for exports
1	2731	−34067	32681	−4116	32681	36797	55938	17284	85889	47235	34538	38654
2	17205	918	16993	706	16287	16287	220	212	8	0	8	8
3	24776	9642	24746	9612	15191	15134	198	87	168	57	168	111
4	8193	−5202	15773	2378	13941	13395	131	−7034	7711	546	7711	7164
5	580	−675	1033	−222	1033	1255	7634	5844	8086	6297	1568	1790
6	6029	−23892	27336	−2584	27336	29921	46355	6109	67662	27417	37661	40245
7	2539	−4016	6055	−500	6055	6555	28551	7007	32067	10522	21044	21545
8	1774	1092	618	−65	618	683	19090	10630	17933	9473	8395	8460
9	647	−1245	893	−998	1871	1892	736	−177	983	69	893	913
10	2288	−6518	672	−8134	8735	8806	2513	1770	896	154	672	743
11	28522	9382	27266	8126	19162	19140	1483	1278	227	22	227	204
12	50965	26847	48050	23932	25201	24118	16554	3997	13640	1083	13640	12557
13	1152	−2917	4032	−37	4032	4069	9820	−1680	12700	1200	11464	11501
14	32013	17815	40246	26048	16157	14198	7924	−9175	16157	−941	19058	17098
15	1581	−218	1675	−124	1675	1799	19165	6292	19258	6386	12748	12873
16	33332	19130	33171	18970	15452	14201	12646	1411	12486	1250	12486	11236
17	8536	−14112	19398	−3249	22033	22647	11811	−8202	22674	2661	19398	20013
18	30714	26204	28736	24226	5520	4510	5568	2988	3591	1010	3591	2581
19	36438	25743	23452	12757	11624	10695	20695	13915	7709	929	7709	6780
20	11963	6392	7522	1951	5776	5571	7154	4646	2713	205	2713	2508

21	2606	2472	2287	2153	151	134	470	−134	151	−454	621	604
22	8162	7806	8998	8642	879	356	43	−361	879	475	928	404
23	7046	−1731	17762	8985	10756	8777	40	−27486	10756	−16770	29505	27526
24	0	−20	15	−5	15	20	6598	3856	6613	3871	2737	2742
25	0	0	0	0	0	0	4057	4057	4057	4057	0	0
26	649	649	0	0	0	0	26521	26521	25872	25872	0	0
27	3207	−2820	5878	−148	5878	6027	22415	1779	25087	4451	20488	20636
28	142	−276	58	−361	410	418	542	476	457	391	58	66
29	1135	−860	1365	−630	1950	1995	2428	1018	2658	1248	1365	1410
30	0	−5336	4643	−693	4643	5336	35899	19938	40542	24581	15268	15961
31	1727	1051	623	−53	623	676	13693	9247	12589	8143	4393	4446
32	2314	1094	3327	2107	1246	1220	234	−1153	1246	−140	1413	1386
33	0	0	0	0	0	0	13498	13498	13498	13498	0	0
34	13615	13035	8385	7805	685	580	5915	4438	685	−792	1583	1477
35	759	−887	793	−853	1636	1646	70	−43	104	−10	104	114
36	2481	−221	2481	−221	2702	2702	0	0	0	0	0	0
37	0	0	0	0	0	0	1229	1229	1229	1229	0	0
38	633	633	0	0	0	0	4663	4663	4030	4030	0	0
39	103	−685	618	−170	618	788	31031	28028	31546	28543	2833	3003
40	61	61	0	0	0	0	7624	7624	7562	7562	0	0
41	1013	884	29	−100	126	129	3563	3530	2579	2547	29	32
42	145	145	0	0	0	0	23741	23741	23596	23596	0	0
Sum or mean	347775	1555	417612	3218	282699	282474	478459	4325	548296	5988	297014	296790

Source: See Table 1.

TABLE 4. Alternative estimates of supply multipliers in 2007: Province of Hubei.

Sector	Description	Official data	CHARM	CB approach
1	Agriculture, forestry, animal husbandry and fishing	1.648	1.862	1.920
2	Coal mining and washing	1.137	1.135	1.145
3	Oil and gas mining	1.107	1.055	1.059
4	Metal mining and selecting	1.583	1.684	1.728
5	Mining and selecting of non-metalliferous ore and other minerals	2.190	2.243	2.366
6	Food manufacturing and tobacco processing	2.138	2.529	2.653
7	Textile industry	2.527	2.928	3.117
8	Manufacturing of textile clothing, shoes, hats, leather and down	2.609	2.976	3.175
9	Wood processing and furniture manufacturing	2.272	2.756	2.912
10	Paper, printing, stationery and sporting goods	2.274	2.632	2.866
11	Oil processing, coking and nuclear fuel processing	1.788	1.521	1.548
12	Chemical industry	2.150	2.172	2.394
13	Manufacturing of non-metallic minerals	2.280	2.532	2.643
14	Metal smelting and press processing	2.140	2.200	2.347
15	Fabricated metal products	2.275	2.732	2.904
16	Manufacturing of general and special equipment	2.073	2.152	2.417
17	Manufacturing of transportation equipment	2.092	2.771	3.142
18	Manufacturing of electrical machinery and equipment	2.113	1.844	2.018
19	Manufacturing of communication equipment, computers and other electronic equipment	1.909	1.868	2.434
20	Manufacturing of instruments, equipment for cultural industries, and office machinery	1.834	1.689	2.221
21	Arts, crafts and other manufacturing	2.597	2.390	2.533
22	Waste and scrap	1.294	1.070	1.072
23	Electric power, heat power production and supply	1.815	2.275	2.329

24	Gas production and supply	1.575	2.097	2.129
25	Water production and supply	2.221	2.156	2.214
26	Construction	2.607	2.723	2.834
27	Transport and storage	1.943	2.010	2.106
28	Post	1.888	2.047	2.186
29	Information transmission, computer services and software	1.528	1.751	1.871
30	Wholesale and retail trade	1.471	1.816	1.876
31	Hotels and catering services	2.145	2.351	2.461
32	Financial intermediation	1.656	1.579	1.622
33	Real estate	1.602	1.341	1.367
34	Leasing and business services	2.191	1.926	2.207
35	Research and development	1.588	2.002	2.120
36	Comprehensive technology services	1.521	1.725	1.802
37	Management of water conservancy, environment and public facilities	1.556	2.020	2.098
38	Services to households and other services	1.914	2.138	2.270
39	Education	1.588	1.942	2.016
40	Health, social security and social welfare	2.194	2.434	2.561
41	Culture, sports and entertainment	1.900	2.200	2.388
42	Public management and social organization	1.661	1.999	2.071
Mean		1.919	2.078	2.218

Source: See Table 1.