University of Groningen

Modeling the short-run effect of fiscal stimuli on GDP

Chen, Quanrun; Dietzenbacher, Erik; Los, Bart; Yang, Cuihong

Published in:
Economic Modelling

DOI:
[10.1016/j.econmod.2016.05.016](https://doi.org/10.1016/j.econmod.2016.05.016)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2016

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Chen, Q., Dietzenbacher, E., Los, B., & Yang, C. (2016). Modeling the short-run effect of fiscal stimuli on GDP: A new semi-closed input-output model. *Economic Modelling*, 58, 52-63.
<https://doi.org/10.1016/j.econmod.2016.05.016>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Modeling the short-run effect of fiscal stimuli on GDP: A new semi-closed input–output model

Quanrun Chen^{a,*}, Erik Dietzenbacher^b, Bart Los^b, Cuihong Yang^c

^a School of Statistics, University of International Business and Economics, Beijing 100029, PR China

^b Faculty of Economics and Business, University of Groningen, PO Box 800, 9700 AV Groningen, The Netherlands

^c Academy of Mathematics and Systems Science, Chinese Academy of Sciences, Beijing 100190, PR China

ARTICLE INFO

Article history:

Received 25 November 2015

Received in revised form 17 May 2016

Accepted 17 May 2016

Available online 31 May 2016

JEL classification:

C67

E27

E62

Keywords:

Input–output model

Household consumption

Multiplier effect

Government spending

ABSTRACT

In this study, we propose a new semi-closed input–output model, which reconciles input–output analysis with modern consumption theories. It can simulate changes in household consumption behavior when exogenous stimulus policies lead to higher disposable income levels. It is useful for quantifying the short-run effects of fiscal stimuli on GDP and its industry-level value added components. We illustrate the use of the model by estimating the short-run effect of the 4 trillion yuan stimulus package on China's GDP. Our results show that this stimulus package might have led to an increase in GDP of more than 3 trillion yuan, which is 9.5% of China's GDP in 2008. This result compares well to actual changes in GDP as observed in the years immediately after the introduction of the package.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

In this paper, we introduce a new methodology to arrive at sensible predictions of the short-run effect of fiscal stimuli on GDP. Introducing such stimuli has been a way adopted by a number of governments around the world to fight the adverse effects of the recent global financial crisis and will most probably be a policy adopted in the future as well. Stimulated demand (by a government) for the products of some industries will directly lead to higher output levels of these industries. The higher output levels will in their turn increase the outputs of other industries, via backward linkages. The increases in household income associated with such higher levels of economic activity will induce more household consumption, driving the output of production sectors up further. Hence, in the short run, massive fiscal stimuli might well lead to considerable jumps in GDP. These favorable effects are reduced, however, if the increased demand for intermediate inputs, capital goods and consumer products is partly met by foreign suppliers. In addition, households may

expect that their future income will be affected by the fiscal stimuli. For instance, households may anticipate that the government will increase tax rates in the future, to finance the public deficit caused by the stimuli. Thus, part of the effects may end up in savings accounts, rather than in increased household consumption.

We construct our estimates of the effects on the basis of industry-level indicators, instead of relying on macroeconomic information. Since the production processes of final products differ in terms of the required inputs (such as capital, labor, domestically produced and imported intermediate inputs), an increase in the demand for one product will cause larger effects than an equal increase in the demand for another product. Our indicators are based on input–output tables and associated models, which allow for careful consideration of the particular composition of fiscal stimuli and the indirect effects that it might evoke. Input–output models can also yield accurate estimates of the import leakage effect described above, since these effects vary across the production processes of final products as well.

With regard to the above-mentioned savings leakage effects, we think that traditional input–output models are less insightful. In the popular static open model, household consumption (and therefore savings) levels are completely insensitive to changes in disposable income, while the so-called semi-closed input–output model assumes that the current consumption is completely determined by

* Corresponding author.

E-mail addresses: qrchen@amss.ac.cn (Q. Chen), h.w.a.dietzenbacher@rug.nl (E. Dietzenbacher), b.los@rug.nl (B. Los), chyang@iss.ac.cn (C. Yang).

the current income.¹ According to widely accepted theories about consumption behavior (such as the relative income hypothesis and the life cycle-permanent income hypothesis), household consumption is also determined by past consumption levels, expectations about future income and many other factors. These tend to have a dampening effect on increases in household consumption. Therefore, semi-closed input–output models are likely to overestimate linkages between the household sector and the production sector, which leads to an upward bias in estimates of GDP jumps following a positive income shock.

To address this problem, we develop a new semi-closed input–output model, which reconciles input–output analysis with consumption theory. In our framework, household consumption is split into endogenous consumption and exogenous consumption. Endogenous consumption is determined by the current household income, while exogenous consumption is not. We assume that fiscal stimuli only lead to changes in endogenous consumption levels and the associated output increases.

As an application of our new model, we estimate the short-run effect of the 4 trillion yuan stimulus package on China's GDP. To alleviate the recessionary impact of the global financial crisis on growth, the Chinese central government announced a stimulus package in the fourth quarter of 2008. The announced package involved additional investments amounting to 4 trillion yuan, to be injected into the economy from the fourth quarter of 2008 till 2010. Most of the investment projects would focus on infrastructure construction.² As discussed before, the stimulus package must have led to higher output levels of construction industry and those industries related to equipment and instruments as well as their related upstream industries. Meanwhile, more household consumption was induced. The stimulus package would also lead to import leakage effects and savings leakage effects. These combined effects on China's GDP can be modeled well by our new semi-closed input–output model.

Some researchers also quantified the consequences of the Chinese stimulus package, using different approaches. We consider the industry-level nature of our model as an advantage of our approach over the macro-economic computable general equilibrium models used by He et al. (2009) and Whalley and Zhao (2013), since differences in the industrial composition of stimulus packages are explicitly taken into account.³ Some of the properties of our novel semi-closed input–output model resemble those of dynamic computable general equilibrium (CGE) models, which sometimes explicitly model intertemporal consumption maximization by households. In Diao et al. (2012), which is the only dynamic CGE analysis addressing effects of the stimulus package of which we are aware, such an assumption is not made. Consumers are supposed to maximize their consumption in every period (after having set a fixed proportion of their income aside as savings), and the dynamic aspects of the model relate to investment behavior only. Compared to the Diao et al. (2012) model, our model is more useful for quantifying short-run effects. Short-run effects are difficult to model in a CGE framework, because CGE models are generally silent on the issue of how long it takes the economy to reach a new equilibrium. The strict dichotomy between quantities and prices can be considered as a downside of our model, but is less of an issue as long as the focus is on the analysis of short-run effects.⁴

The remainder of this paper digs deeper into the advantages and disadvantages of the conventional semi-closed input–output model (Section 2), and describes the construction of our new model (Section 3) and the econometrics required to operationalize the distinction between endogenous and exogenous consumption (Section 4). Next, as an illustration, Section 5 estimates the short-term impact of the 4 trillion yuan stimulus package on China's GDP by using our new model and compares the results with those obtained by previous models and actual GDP changes in China immediately after the introduction of the policy. Section 6 concludes.

2. The semi-closed input–output model

The traditional input–output model can be expressed as $\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}(\mathbf{c} + \mathbf{f} + \mathbf{e})$, where $\mathbf{x}$ represents the gross output vector, $\mathbf{A}$ stands for the domestic input coefficients matrix, $\mathbf{c}$ is the household consumption vector, $\mathbf{f}$ represents the vector of domestic final demands other than household consumption, $\mathbf{e}$ is the vector with (gross) exports, and $\mathbf{I}$ is the identity matrix of appropriate dimensions.⁵ In the traditional input–output model, household consumption is treated as an exogenous final demand category, so there is no linkage between the household sector and the production sector. In reality, however, the household sector is closely related to the production sector via an income–consumption relationship. Households earn income from the production sector and spend this on the products produced by the production sector. The Leontief inverse matrix $(\mathbf{I} - \mathbf{A})^{-1}$ as calculated in the traditional static open input–output model takes all linkages between production sectors into account, but does not consider the link from income to consumption.

To incorporate the income–consumption relationship into input–output models, many researchers have studied the semi-closed input–output model. In this model, the household sector is moved into the intermediate delivery matrix and treated as an endogenous sector. The inputs of this sector are consumption commodities and its output is labor. According to Miyazawa's formulation (Miyazawa, 1976), the basic structure of the semi-closed input–output model is as follows:

$$\begin{bmatrix} \mathbf{A} & \bar{\alpha} \\ \mathbf{w}' & 0 \end{bmatrix} \begin{bmatrix} \mathbf{x} \\ x_{n+1} \end{bmatrix} + \begin{bmatrix} \mathbf{f} + \mathbf{e} \\ h \end{bmatrix} = \begin{bmatrix} \mathbf{x} \\ x_{n+1} \end{bmatrix}. \quad (1)$$

Like in the static open model, $\mathbf{A} = (a_{ij})_{n \times n}$ is still the matrix of domestic input coefficients, $\mathbf{x} = (x_i)_{n \times 1}$ is the vector of gross outputs of production sectors, $\mathbf{f} = (f_i)_{n \times 1}$ is the vector of domestic final demands other than household consumption (including government consumption and investment demand, among other things), and $\mathbf{e} = (e_i)_{n \times 1}$ is the vector of exports. The household sector enters the semi-closed model as the $(n + 1)$ th industry: x_{n+1} is total household income, h is the exogenous income of the household sector, $\bar{\alpha} = (\bar{\alpha}_i)_{n \times 1}$ is the vector of consumption coefficients, and $\mathbf{w} = (w_j)_{n \times 1}$ is the vector of labor input coefficients.⁶ The consumption coefficients $\bar{\alpha}_i$ are defined as $\bar{\alpha}_i = c_i/x_{n+1}$, where c_i is consumption of the household sector of the products produced by industry i . The labor input coefficients are defined as $w_j = h_j/x_j$, where h_j represents the labor compensation paid by industry j .

Previous studies have pointed out that actual household consumption behavior is not accurately described by this model, because the consumption coefficients are assumed constant and differences between

¹ See, e.g., Miyazawa (1976), Batey et al. (1987), Dietzenbacher and Günlük-Şenesen (2003), Yang et al. (2008) and Hong and Li (2015).

² McKissack and Xu (2011) presented a detailed account of the composition of the stimulus package, including information on the governmental accounts from which the package was funded.

³ Burdekin and Weidenmier (2015) also assessed the economic effects at the level of industries. As opposed to the analysis of this paper, they adopted a financial perspective, investigating the post-stimulus gains using stock market data.

⁴ Rose (1995) gave a systematic comparison between the two approaches and concluded that input–output models and CGE models are both useful for impact analysis, each having their specific advantages and disadvantages.

⁵ Throughout the paper, bold capital symbols represent matrices and bold lowercase symbols stand for column vectors. The number of elements in a vector or the columns of matrices is identical to the number of industries discerned. Scalars are indicated by italicized lowercase symbols.

⁶ In Miyazawa's model, $\mathbf{w}$ is a vector of value added ratios. According to Miller and Blair's (2009) description of Miyazawa's model, $\mathbf{w}$ is a vector of labor compensation coefficients, i.e. a vector of wage bills by industry over gross output levels by industry. The difference is mainly due to capital income. In the case of China, a relatively large part of capital income is earned by foreign investors. Therefore, it will not play an important role in consumption decisions by Chinese households.

consumption patterns of different types of households are ignored (see, e.g., Batey et al., 1987; Batey and Weeks, 1989; Cloutier and Thomasin, 1994; Wakabayashi and Hewings, 2007; Miller and Blair, 2009). First, the constant consumption coefficients reflect the assumption that the household sector will spend constant proportions ($\bar{\alpha}_i$) of additional income on product i , irrespective of the additional amount of household earnings. This is a quite strong assumption, since it does not distinguish between “income to new earners” and “additional income to existing earners”, while many empirical studies on Engel’s Law show that consumption patterns vary across households with different characteristics, such as income level and age.⁷

We feel that the semi-closed input–output model features another limitation, to which much less attention has been paid. In the semi-closed input–output model, household consumption is fully endogenized (i.e., the consumption coefficients are defined as $\bar{\alpha}_i = c_i/x_{n+1}$). Household consumption is assumed to be determined by the current income only. Several well-accepted theories about consumption behavior, however, argue that the current consumption is not only determined by the current income, but also by a variety of other factors. For instance, according to Duesenberry’s (1949) relative income hypothesis (RIH), the current consumption is also affected by previous consumption peaks, because consumption behavior is quite “irreversible” over time: it is often difficult for a household to reduce its consumption level once it has been attained. According to the life cycle/permanent income hypothesis (LCPIH), developed by Friedman (1957), Ando and Modigliani (1963), and Hall (1978), consumers are forward-looking. They can advance or defer consumption depending on their plans and expectations, so as to maximize their utility levels intertemporally. The Miyazawa model is not consistent with these consumption theories. Using this model will most likely lead to an overestimated linkage between the household sector and the production sector. Hence, results regarding output and employment effects of exogenous shocks will most probably be biased in an upward sense as well.

This suggests that estimating the impacts of the massive stimulus package of the Chinese government requires the development of a new model, which reconciles input–output analysis with modern consumption theory. To do this, aggregate household consumption should be decomposed into an endogenous component and an exogenous component. The former is determined by the current income, and the latter is determined by other factors. Only endogenous consumption should be incorporated into the matrix with input coefficients.

3. A new semi-closed input–output model

As we discussed in the previous section, disaggregating the household sector into different groups has been a topic of a substantial number of studies already. Hence, we will not focus on this issue. Our model assumes that there is only one household, which acts as a representative agent.

3.1. Framework

Implementing input–output models empirically requires the availability of input–output tables. Table 1 illustrates the expanded input–output table needed to develop the model that we propose in this paper.

A first important feature is that imports are excluded from the intermediate input flows, household consumption, and other final demand. This distinction between flows of domestically produced and imported products is necessary to avoid a situation in which effects of the

Table 1

Schematic representation of the expanded input–output table.

	Industries				Household sector	Other domestic final demands	Exports	Exogenous income	Gross output
	1	2	...	n					
Industry 1	$Z = (z_{ij})_{n \times n}$				c_1^{en}	c_1^{ex}	f_1	e_1	x_1
Industry 2					c_2^{en}	c_2^{ex}	f_2	e_2	x_2
...					...	...	...	...	...
Industry n					c_n^{en}	c_n^{ex}	f_n	e_n	x_n
Household sector	h_1	h_2	...	h_n				h	x_{n+1}
Other value added	v_1	v_2	...	v_n					
Imports	m_1	m_2	...	m_n	c_m^{en}	c_m^{ex}	f_m		
income tax and saving of household					v				
Gross input	x_1	x_2	...	x_n	x_{n+1}				

stimulus package as observed in other countries would inadvertently be included in effects on the Chinese economy. $Z = (z_{ij})_{n \times n}$ stands for the matrix of deliveries of domestically produced intermediate inputs. z_{ij} thus gives the value of the shipments of Chinese industry i to Chinese industry j . m_j represents the aggregated value of all products imported by industry j .

The second aspect of the input–output table as depicted in Table 1 deserving specific attention is the representation of household consumption. As argued in the previous section, we partially decouple consumption growth and income growth, by distinguishing between endogenous consumption and exogenous consumption. This distinction is reflected in the inclusion of two columns for household consumption, rather than the single column c in Section 2. Hence, c_i^{en} and c_i^{ex} indicate the values of endogenous consumption and exogenous consumption of products delivered by domestic industry i to domestic consumers, respectively. In a similar vein, c_m^{en} and c_m^{ex} represent the endogenous and exogenous household consumption of imported products.

The remaining columns are less specific to our use of input–output tables. f_i gives the value of the products of domestic industry i used for final demand other than household consumption, while f_m is its counterpart related to other final demand for all imported products taken together. e_i is the exports of industry i and x_i stands for the gross output of industry i .

In the rightmost column, x_{n+1} is total household income.⁸ It is composed of the sum over h_j (the endogenous labor income of the household sector earned in industry j) and h (the exogenous income of the household sector). Exogenous income is income not related to production in the accounting period for which the input–output table is constructed. Income from wealth and income from transfers are important sources of this type of income. Endogenous income is income from labor compensation related to production. Labor compensation includes compensation of employees and income of self-employed individuals, like shop-owners and farmers.

v_j is “other value added” generated in industry j . It equals the value added of industry j minus labor compensation h_j . v stands for the income taxes and savings of the household sector. It equals total household income minus aggregate household consumption (both endogenous consumption and exogenous consumption).⁹

⁸ To be consistent with the input–output accounting table for China, all income concepts used in this paper refer to gross incomes before tax. In Table 1, taxes on income are part of x_{n+1} .

⁹ In the analytical framework deployed by others (see Cloutier and Thomasin, 1994; Miller and Blair, 2009), there are positive values in the shaded area of Table 1. They define these as household purchases of labor services. However, we set them to 0 in our framework, since a separate industry labeled *household service and other social services* is included in the Chinese input–output tables. Household purchases of labor services are captured by labor compensation in this industry. In Section 4, we will describe in detail how to construct the row flows and the column flows for the household sector in our new framework.

⁷ An approach to address this problem is to disaggregate the household sector into several groups according to specific characteristics. For example, the household sector could be disaggregated into groups based on income levels (see e.g. Cloutier and Thomasin, 1994). Income mobility should be taken into account in this situation, since economic growth induced by an increase in government spending might lead to households shifting from one income-specific group to another.

3.2. Model

From Table 1, we can derive the following accounting identities for the production sector and the household sector:

$$\sum_{j=1}^n z_{ij} + c_i^{en} + c_i^{ex} + f_i + e_i = x_i \quad (i = 1, 2, \dots, n) \quad (2)$$

$$\sum_{j=1}^n h_j + h = x_{n+1} \quad (3)$$

$$\sum_{i=1}^n z_{ij} + m_j + h_j + v_j = x_j \quad (j = 1, 2, \dots, n) \quad (4)$$

$$\sum_{i=1}^n c_i^{en} + c_m^{en} + \sum_{i=1}^n c_i^{ex} + c_m^{ex} + v = x_{n+1}. \quad (5)$$

Eq. (2) expresses that the gross output (x_i) of each industry is sold to one of the following use categories: intermediate use ($\sum_{j=1}^n z_{ij}$), endogenous consumption (c_i^{en}), exogenous consumption (c_i^{ex}), other domestic final demands (f_i), or exports (e_i). Eq. (3) indicates that the sum of endogenous income ($\sum_{j=1}^n h_j$) and exogenous income (h) equals total income (x_{n+1}). Eq. (4) states that the value of gross output (x_j) of each industry consists of the value of domestic intermediate inputs ($\sum_{i=1}^n z_{ij}$), imported intermediate inputs (m_j), and compensation for primary inputs ($h_j + v_j$). Eq. (5) indicates that total household income (x_{n+1}) flows to household consumption ($\sum_{i=1}^n c_i^{en} + c_m^{en} + \sum_{i=1}^n c_i^{ex} + c_m^{ex}$), and income taxes and savings (v).

We can derive our model from Eqs. (2) and (3). Before doing so, we introduce some notation:

$\mathbf{A} = (a_{ij})_{n \times n}$ is a matrix of domestic input coefficients: $a_{ij} = z_{ij}/x_j$;
 $\mathbf{w} = (w_j)_{n \times 1}$ is a column vector of endogenous income coefficients: $w_j = h_j/x_j$;
 $\boldsymbol{\alpha} = (\alpha_i)_{n \times 1}$ is a column vector of the endogenous consumption coefficients for domestic products: $\alpha_i = c_i^{en}/x_{n+1}$;
 $\mathbf{g} = (g_i)_{n \times 1}$ is a column vector of the exogenous final demands for domestic products, with $g_i = c_i^{ex} + f_i + e_i$.

Eqs. (2) and (3) can now be expressed as:

$$\begin{cases} \sum_{j=1}^n a_{ij}x_j + \alpha_i x_{n+1} + g_i = x_i & (i = 1, 2, \dots, n) \\ \sum_{j=1}^n w_j x_j + h = x_{n+1} \end{cases} \quad (6)$$

In matrix form, this reads as:

$$\begin{bmatrix} \mathbf{A} & \boldsymbol{\alpha} \\ \mathbf{w}' & 0 \end{bmatrix} \begin{bmatrix} \mathbf{x} \\ x_{n+1} \end{bmatrix} + \begin{bmatrix} \mathbf{g} \\ h \end{bmatrix} = \begin{bmatrix} \mathbf{x} \\ x_{n+1} \end{bmatrix}. \quad (7)$$

Solving Eq. (7) yields the final model:

$$\mathbf{x}^* = (\mathbf{I} - \mathbf{A}^*)^{-1} \mathbf{g}^* = \mathbf{L}^* \mathbf{g}^* \quad (8)$$

with $\mathbf{A}^* = \begin{bmatrix} \mathbf{A} & \boldsymbol{\alpha} \\ \mathbf{w}' & 0 \end{bmatrix}$, $\mathbf{x}^* = \begin{bmatrix} \mathbf{x} \\ x_{n+1} \end{bmatrix}$, $\mathbf{g}^* = \begin{bmatrix} \mathbf{g} \\ h \end{bmatrix}$, and $\mathbf{L}^* = (\mathbf{I} - \mathbf{A}^*)^{-1}$.

3.3. Multipliers

Some useful multipliers can be obtained by calculating the extended Leontief inverse matrix $\mathbf{L}^*$. $\mathbf{L}^*$ can be expressed as (see, for example, Luptacik and Böhm, 1999):

$$\mathbf{L}^* = (\mathbf{I} - \mathbf{A}^*)^{-1} = \begin{bmatrix} \mathbf{L}_{11}^* & \mathbf{L}_{12}^* \\ \mathbf{L}_{21}^* & \mathbf{L}_{22}^* \end{bmatrix} = \begin{bmatrix} \mathbf{L} \left(\mathbf{I} + \boldsymbol{\alpha} \frac{1}{1 - \mathbf{w}' \mathbf{L} \boldsymbol{\alpha}} \right) \mathbf{w}' \mathbf{L} & \mathbf{L} \boldsymbol{\alpha} \frac{1}{1 - \mathbf{w}' \mathbf{L} \boldsymbol{\alpha}} \\ \frac{1}{1 - \mathbf{w}' \mathbf{L} \boldsymbol{\alpha}} \mathbf{w}' \mathbf{L} & \frac{1}{1 - \mathbf{w}' \mathbf{L} \boldsymbol{\alpha}} \end{bmatrix} \quad (9)$$

where $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$. The vector of output multipliers $\mathbf{m}(o) = [m_1(o), m_2(o), \dots, m_n(o)]$ can be obtained by summing over the cells in a column of $\mathbf{L}_{11}^*$, that is, $\mathbf{i}' \mathbf{L}_{11}^*$.¹⁰ $m_j(o)$ indicates the gross output of all industries taken together required to satisfy one unit of exogenous final demand for the output of industry j . Similar to $\mathbf{i}' \mathbf{L}_{11}^*$, $\mathbf{i}' \mathbf{L}_{12}^*$ indicates the gross output of all industries induced by one unit of exogenous income of the household sector; we define it as the “income-driven gross output multiplier”. The j th element of the “multi-sector income multiplier” vector $\mathbf{L}_{21}^*$ indicates the total household labor income (earned in all production industries) induced by one unit of exogenous final demand for the products of industry j . $\mathbf{L}_{22}^*$ indicates the total household income induced by one unit of exogenous income of the household sector. The endogenous consumption multiplier matrix can be expressed as $\mathbf{M}(enc) = \boldsymbol{\alpha} \mathbf{L}_{21}^* = (\mathbf{I} - \boldsymbol{\alpha} \mathbf{w}' \mathbf{L})^{-1} - \mathbf{I}$. The element $m_{ij}(enc)$ in $\mathbf{M}(enc)$ gives the household consumption of industry i 's products induced by one unit of exogenous final demand for industry j 's products.

Finally, the value added multiplier matrix is given by $\mathbf{M}(v) = \boldsymbol{\omega} \mathbf{L}_{11}^*$, where $\boldsymbol{\omega}$ is a diagonal matrix, which contains the elements of the value added coefficient vector $\boldsymbol{\omega}' = [(v_1 + h_1)/x_1, (v_2 + h_2)/x_2, \dots, (v_n + h_n)/x_n]$ on its main diagonal. The element $m_{ij}(v)$ in $\mathbf{M}(v)$ indicates the total (both direct and indirect) value added in industry i caused by a unit of exogenous final demand for the products of industry j . We will use this multiplier to estimate the short-run effect of the stimulus package on China's GDP.

3.4. A decomposition of consumption

To make our model operational, we need a specific consumption decomposition formula that should enable us to split household consumption into endogenous consumption (determined by the current household income) and exogenous consumption (determined by other factors).

According to the relative income hypothesis (RIH), the lifecycle/permanent income hypothesis (LCPIH) and related theories, there are many other factors influencing aggregate consumption besides the current income. Examples are past consumption levels (Duesenberry, 1949; Dennis, 2009), expected future income (Carroll, 1994; Muellbauer and Lattimore, 1999; Luengo-Prado and Sørensen, 2008), interest rates (Attanasio and Weber, 1993; Erlandsen and Nymoen, 2008), and demographic issues such as the age structure of the population (Erlandsen and Nymoen, 2008). Moreover, studies on consumer preferences (e.g., Clements and Selvanathan, 1994; Barnett and Serletis, 2008) show that commodity prices and consumers' tastes play important roles in determining the shares of product categories in consumption budgets.

Taking these insights on board, we specify the consumption decomposition formula as:

$$\begin{cases} c_{it} = c_{it}^{en} + c_{it}^{ex} \\ c_{it}^{en} = \alpha_{it}(\bar{c}, r, d, p, \lambda, \dots) x_{(n+1)t} \\ c_{it}^{ex} = \beta_i c_{i(t-1)} + \varepsilon_{it} \end{cases} \quad (10)$$

¹⁰ In this paper, $\mathbf{i}' = (1, 1, \dots, 1)$ denotes a summation vector of appropriate length.

c_{it} is the aggregated household consumption of product i . α_{it} and $x_{(n+1)t}$ have been defined already as the endogenous consumption coefficient of product i and the total household income, respectively. Together, they determine endogenous consumption c_{it}^e . The second equation in Eq. (10) indicates that the endogenous consumption coefficient α_{it} depends on the expectations of households regarding their future incomes $\bar{e}$, on the interest rate r , the demographic characteristics summarized in d , the commodity price index p , a taste parameter λ , and other factors. Since these variables change over time, the endogenous consumption coefficients α_{it} also vary over time. As discussed in Section 2, it has proven difficult for households to reduce consumption levels once attained, so previous consumption peaks are an important determinant of the current consumption. Since aggregate consumption is usually growing, we use consumption in the previous year $c_{i(t-1)}$ as a measure of the most recent consumption peak. β_i , which is assumed to be stable over time, determines the effect of the previous consumption peak on the current household consumption. β_i , $c_{i(t-1)}$ and a random error term ε_{it} together determine exogenous consumption c_{it}^x .

The estimation of the function α_{it} is key in giving the consumption decomposition formula empirical content. Some of its determinants are unobservable and it is difficult to find good proxy variables for these. Moreover, its functional form is difficult to specify, because it is not clear how households weight changes in the relevant variables and whether interaction terms between them play a role. Considering these difficulties, we assume that households have rational expectations on the influencing factors (i.e. $\bar{e}$, r , d , p , λ , ...) of the endogenous consumption coefficient. This assumption states that households use all available information up to now to make optimal forecasts on the future dynamics of the influencing factors. At any time, households choose endogenous consumption coefficients based on their current expectations on the future levels of the influencing factors to maximize their utility of the whole life. Households change the endogenous consumption coefficient only when they receive new (unpredictable) information which changes their expectations on the influencing factors. The rational expectation assumption implies that the endogenous consumption coefficient follows a random walk process: $\alpha_{it} = \alpha_{it-1} + \mu_{it}$, $\mu_{it} \sim \text{NIID}(0, \sigma_{\mu}^2)$ (Hall, 1978; Mankiw, 2010). The new information which changes households' expectations on the influencing factors is unpredictable, which is thus modeled by the white noise $\mu_{it} \sim \text{NIID}(0, \sigma_{\mu}^2)$.

Given the above specifications, the consumption decomposition formula can be estimated applying a maximum likelihood estimation method with the Kalman filter (see Appendix 1) on the time varying parameter model in Eq. (11):

$$\begin{cases} c_{it} = \alpha_{it}x_{(n+1)t} + \beta_i c_{i(t-1)} + \varepsilon_{it} \\ \alpha_{it} = \alpha_{it-1} + \mu_{it} \end{cases} \quad (11)$$

It consists of the “measurement equation” $c_{it} = \alpha_{it}x_{(n+1)t} + \beta_i c_{i(t-1)} + \varepsilon_{it}$ and the “transition equation” $\alpha_{it} = \alpha_{it-1} + \mu_{it}$, in which ε_{it} and μ_{it} are assumed to be mutually serially independent Gaussian disturbances. The measurement equation defines how the measurements (i.e., the consumption c_{it}) are derived from the unobserved state (i.e., the endogenous consumption coefficient α_{it}). The transition equation explains how the unobserved state (i.e., the endogenous consumption coefficient) evolves over time. As discussed before, we assume that it follows a random walk process.¹¹ Our target is to discover the unobserved state (α_{it}) from the noisy measurements (c_{it}). Based on estimated results, we can easily obtain the endogenous consumption $c_{it}^e = \alpha_{it}x_{n+1}$ (i.e., the consumption determined by the current household income and endogenous consumption coefficient together) and

the exogenous consumption $c_{it}^x = c_{it} - c_{it}^e$ (i.e., the consumption determined by other factors).

4. Implementation of the model: the Chinese stimulus package of 2008

In this section, we illustrate how the model introduced in the previous section can be implemented empirically. We address the case of the large (4 trillion yuan) fiscal stimulus package introduced by the Chinese government in 2008. The selection of this case has two advantages. First, we can compare our model results with those obtained by applying other types of models (since this case has been addressed by others as well), and second, we can compare our model results to the actual changes in Chinese GDP in the first years after the government investments.

The results will be discussed in the next section, while this section is devoted to a description of the steps needed to implement the model empirically in the context of this illustration for China.

4.1. Endogenous consumption coefficients for broad consumption categories

In order to estimate both parts of Eq. (11), time series data are needed. These cannot be found in input–output tables, since such tables are published in China only once every five years. The household survey data in *China Statistical Yearbook* (NBS, various years), however, provides annual data about per capita income levels for both rural and urban households, and expenditures of these households on eight consumption categories: food; clothing; housing; home equipment, facilities and services; health and medical care; transportation and communication; education, cultural and recreational services; and miscellaneous goods and services.

To arrive at endogenous consumption coefficients for these eight categories, we process the data in two steps. First, we multiply per capita

Table 2
Estimated results for the consumption decomposition formula.

	F	C	H	HFS	HM	TC	ECR	M	AC
β_i	0.500	0.395	0.708	0.282	0.523	0.926	0.653	0.785	
α_{it} :									
1989	0.221	0.054		0.051					
1990	0.252	0.057		0.051					
1991	0.238	0.062		0.053					
1992	0.220	0.064		0.054					
1993	0.223	0.069	0.029	0.056			0.020		
1994	0.204	0.070	0.029	0.059	0.013	0.009	0.022		0.405
1995	0.198	0.070	0.030	0.059	0.014	0.009	0.024		0.404
1996	0.191	0.070	0.029	0.061	0.016	0.010	0.025		0.400
1997	0.181	0.060	0.029	0.060	0.016	0.011	0.027		0.383
1998	0.172	0.052	0.029	0.059	0.016	0.013	0.030		0.371
1999	0.171	0.053	0.029	0.060	0.018	0.016	0.032	0.0068	0.385
2000	0.168	0.055	0.028	0.060	0.023	0.019	0.033	0.0092	0.396
2001	0.159	0.057	0.028	0.059	0.022	0.020	0.031	0.0074	0.383
2002	0.159	0.058	0.026	0.057	0.025	0.023	0.033	0.0063	0.387
2003	0.143	0.058	0.025	0.056	0.024	0.024	0.031	0.0047	0.365
2004	0.138	0.060	0.024	0.055	0.025	0.025	0.031	0.0062	0.364
2005	0.137	0.069	0.024	0.057	0.028	0.028	0.030	0.0072	0.380
2006	0.126	0.069	0.025	0.058	0.024	0.027	0.030	0.0068	0.365
2007	0.116	0.073	0.025	0.062	0.025	0.028	0.030	0.0068	0.364
2008	0.108	0.075	0.025	0.063	0.025	0.020	0.026	0.0064	0.349

Notes: (1) F = food; C = clothing; H = housing; HFS = home equipment, facilities and services; HM = health and medical care; TC = transportation and communication; ECR = education, cultural and recreational services; M = miscellaneous goods and services; AC = aggregate consumption; (2) due to differences in the availability of data, the length of the time series of estimates varies across categories. The aggregate endogenous consumption coefficient (AC) is the sum of F, C, H, HFS, HM, TC, ECR, and M. The data about M is not available from 1994 to 1998. For those years, the aggregate endogenous consumption coefficient is the sum of F, C, H, HFS, HM, TC, and ECR; (3) the estimates appear to be robust to choosing different initial values for the maximum likelihood estimation procedure.

¹¹ In reviewing empirical results obtained by means of the Kalman filter, Engle and Watson (1987) found that the simple random walk specification for the transition equation performs well in forecasting the dependent variable of the measurement equation for many datasets.

urban household income and rural household income with the number of urban and rural inhabitants, respectively, and add the two results to obtain total household income. In the same sense, the total expenditures by households on each of the eight consumption categories can be obtained. These variables are needed in Eq. (10). Second, in order to make data for different years comparable, we deflate demand for each consumption category by its corresponding consumer price index, and total household income by the aggregate consumer price index.

Based on the processed data, we estimate the time-varying parameter model (Eq. (11)) for each consumption category separately, by means of the maximum likelihood estimation method with a Kalman filter (see Appendix 1).

Table 2 illustrates changes in the endogenous consumption coefficients α_{it} from 1989 to 2008. The endogenous consumption coefficient of *food* steadily decreased over this period. This is consistent with Engel's law, which says that increases in consumption of basic products as a consequence of increases in income are smaller at high income levels. The endogenous consumption coefficient of *housing* also fell. The endogenous consumption coefficients of *home equipment, facilities and services*, and *transportation and communication*, however, show upward trends. The endogenous consumption coefficient of *clothing* went through three stages of change, increasing from 1989 to 1995, decreasing from 1996 to 1998, and then increasing again from 1999 to 2008. The endogenous consumption coefficients of *health and medical care*, and *education, cultural and recreational services* remained relatively stable.

The impacts of some important events are reflected in these endogenous consumption coefficients. In 2003, for example, China was hit by the SARS epidemic, which prevented many consumers from shopping in crowded places. Almost all endogenous consumption coefficients decreased from 2002 to 2003, and the aggregate endogenous consumption coefficient decreased by 5.6%. In 2008, the global financial crisis also had an impact on household consumption. Pessimistic expectations led to more cautious spending behavior. This might have been the main cause of the decrease of the aggregate endogenous consumption coefficient, by 4.2% between 2007 and 2008.

Based on the estimates for the varying parameters model, we calculate the increase in the consumption of each product category from 2000 to 2008 and decompose it to the contributions of endogenous consumption and exogenous consumption, using Eq. (12).

$$c_{i(t+s)} - c_{it} = [\hat{\alpha}_{i(t+s)}x_{(n+1)(t+s)} - \hat{\alpha}_{it}x_{(n+1)t}] + [\hat{\beta}_i c_{i(t+s-1)} - \hat{\beta}_i c_{i(t-1)}] + [\hat{\varepsilon}_{i(t+s)} - \hat{\varepsilon}_{it}] \quad (12)$$

Table 3
Contributions of endogenous consumption and exogenous consumption to aggregate consumption growth (2000–2008).

Consumption category	ΔC	E_{en}	E_{ex}	
			$E_{c_{t-1}}$	E_e
Food	2598.0	1306.3 (50.3)	1298.5 (50.0)	−6.7 (−0.3)
Clothing	2717.6	1799.0 (66.2)	906.8 (33.4)	11.8 (0.4)
Housing	1137.0	459.9 (40.4)	686.1 (60.4)	−9.1 (−0.8)
Home equipment, facilities and services	1700.9	1311.6 (77.1)	412.3 (24.2)	−23.0 (−1.3)
Health and medical care	1067.7	532.2 (49.8)	537.9 (50.4)	−2.4 (−0.2)
Transportation and communication	3425.0	417.1 (12.2)	3131.5 (91.4)	−123.5 (−3.6)
Education, cultural and recreational services	1247.7	422.1 (33.8)	856.5 (68.6)	−30.8 (−2.5)
Miscellaneous good and services	408.6	88.3 (21.6)	322.7 (79.0)	−2.4 (−0.6)

Note: ΔC denotes the increase in aggregate consumption, in 100 million yuan; E_{en} denotes the contribution of the endogenous consumption; E_{ex} denotes the contribution of the exogenous consumption, which consists of $E_{c_{t-1}}$ (the contribution of previous period consumption), and E_e (the residual). The values in parentheses are the contribution shares of each component in percentage form.

The left hand side of this equation gives the total change in consumption between t and $t + s$ (indicated by ΔC in Table 3 below). The contributions of three sources of change to this total change are represented by the right hand side of the equation. The first term between brackets gives the change in estimated endogenous consumption (E_{en}), the second term represents the changes due to estimated exogenous consumption ($E_{c_{t-1}}$) and the residual is given by the third term (E_e).

The decomposition results in Table 3 show that the relative contributions of the three determinants vary across consumption categories. For *housing, education, cultural and recreational services* and in particular *transportation and communication*, exogenous growth has been dominant. These consumption categories have relatively high β -coefficients as shown in the first row of Table 2. This implies that the increase in the consumption of these product categories has mainly depended on habitual consumption levels or on stable expectations. The consumption growth patterns of *clothing*, and *home equipment, facilities and services* are dominated by endogenous growth. These consumption categories have relatively low β -coefficients. This implies that the consumption of these commodity categories mainly depends on the current income of the household. For *food* and *health and medical care*, we find roughly equal contributions of exogenous and endogenous consumption. For all consumption categories, the residuals are small.

In general, consumption patterns are not identical across countries (see Clements et al., 2006; Lyons et al., 2009). Hence, it should not come as a surprise that our results are only partly in line with the existing evidence for other countries. In their study for Ireland, Lyons et al. (2009) also found that clothing and household equipment are product categories on which consumers are most likely to spend additional income. Karagiannis and Velentzas (2004), however, observed for Greece that changes in the current income are the main driving force for explaining changes in demands for all product categories.

4.2. Linking consumption products to broad consumption categories

To quantify the effects of the stimulus package to fight the effect of the crisis, we need to link changes in consumption levels to an input–output table. The classification of broad consumption categories analyzed in the previous subsection is much less fine-grained than the classification of industry-specific outputs in the Chinese input–output tables. To link results for broad categories to output of industries as discerned in the input–output table, we need a bridge matrix:

$$c^* = B\tilde{c} \quad (13)$$

Like before, $\tilde{c}$ contains household consumption levels, for broad categories. c^* is the vector of consumption levels for the outputs of industries. The bridge matrix $B = (b_{ij})_{n \times m}$ gives the shares of consumption of the output of input–output industry i in the consumption of broad category j (n is the number of input–output industries and m is the number of broad consumption categories).

The only information we have for estimating B is a concordance table linking eight broad categories to the forty-two industries discerned in the input–output table for 2007, and the consumption data for each broad category and each input–output industry. Based on this limited information, we estimate B using a procedure consisting of four steps. First, we reconcile total household consumption in the input–output table with the sum of the consumption of the eight broad categories.¹² Second, we generate $R = (r_{ij})_{42 \times 8}$, which is a matrix that gives initial values for the transaction values of consumption in category j that can be attributed to consumption of the product of input–output industry i . If industry i delivers products included in category j

¹² Some consumption items in the input–output table are not included in the eight broad categories. For instance, the consumption of finance, which is defined as the value of financial intermediation services delivered to households who save and borrow, is not included in the eight categories. We will regard this type of consumption as exogenous.

(according to the concordance table), then $r_{ij} = y_i^c / n_i$ ($j = 1, 2, \dots, 8$), otherwise $r_{ij} = 0$. y_i^c is the revised household consumption of industry i in the first step; n_i is the number of broad categories that contain products from industry i ; and r_{ij} represents the amount of consumption of industry i contained in broad category j . Third, we balance $\mathbf{R}$ by means of the RAS method to make sure that the sum of each row and the sum of each column equals the revised household consumption of the corresponding input–output industry and the consumption of the corresponding broad category, respectively.¹³ Finally, we divide the element in each column by the sum of the cell values in the corresponding column to obtain the estimate of $\mathbf{B}$.¹⁴

The 42 elements of $\mathbf{c}^*$ contain consumption levels by households, which includes consumption demand for imported products. Disregarding generally small indirect effects, the production of these imported products will not have implications for economic activity in China, so we need to have information on demand for domestically produced products. We obtain consumption for domestic products ($\mathbf{c}^d$) by multiplying $\mathbf{c}^*$ with the share of domestic products in the aggregate domestic demand for these products, as found in the input–output table.¹⁵ Finally, based on the converted endogenous consumption coefficients of the input–output industries, the aggregate consumption can be split into the endogenous consumption and the exogenous consumption by Eq. (10).

4.3. The estimation of endogenous income coefficients for input–output industries

As we discussed in Section 3, labor compensation (i.e., compensation of employees and income of self-employed individuals) is a reasonable measure of endogenous income. The industry-specific labor compensation data, however, is not directly available in the 2007 input–output table for China. This table only distinguishes between industry-specific compensation of employees and the industry-specific aggregate of income of self-employed and operating surplus. We therefore estimate the industry-specific labor compensation following the approach used by Chen et al. (2015). Furthermore, we find that the sum of the estimated industry-specific labor compensation is larger than the total household income from labor compensation indicated by the household survey data (NBS, various years). As mentioned before, the household income obtained from the household survey data is used to estimate the endogenous consumption coefficients. Hence, we further proportionally lower the estimated industry-specific labor compensation so that the sum of it equals the total household income from labor compensation indicated by the household survey data. After the endogenous income flow is obtained, the endogenous income coefficient of each industry can further be calculated by dividing each industry's endogenous income over gross output.

Exogenous income (consisting of income from properties and transfers) can easily be obtained from detailed data about property income and transfer income of households in the *China Statistical Yearbook* (NBS, various years).

¹³ RAS is a popular method to recover the entries of a matrix from limited and incomplete multisectoral economic data. See Golan et al. (1994) and Dietzenbacher and Miller (2009) for discussions about this method.

¹⁴ The estimated bridge matrix between eight broad consumption categories and forty-two industries in 2007 China input–output table is listed in Appendix 2.

¹⁵ The shares of domestic products in the aggregate domestic demand can be calculated from input–output tables, using the so-called proportionality assumption. The share for industry i is $(x_i - e_i) / (x_i + \bar{m}_i - e_i)$, where x_i and e_i are the gross output and the exported products of industry i respectively. $\bar{m}_i$ gives the imports of product i , which is available in the original Chinese input–output tables. Note that this differs from m_j , which gives all imports bought by industry j . Dietzenbacher et al. (2013) give a description of a more accurate procedure that can be used if additional data on the nature of traded goods is available.

Table 4

The composition of the 4 trillion yuan stimulus package.

Data source: the website of national development and reform commission of China www.ndrc.gov.cn/xwzx/xwtt/t20090521_280383.htm.

Item	Fund (billion yuan)
1. Low-rent housing and indemnificatory housing construction	400
2. Rural people's livelihood project and rural infrastructure construction	370
3. Railway, highway, airport, water conservancy construction and distribution network enhancement	1500
4. Health, education and culture	150
5. Energy saving and emission reduction, ecological construction project	210
6. Independent innovation and adjustment of industry structure	370
7. Post-quake recovery and reconstruction	1000
Sum	4000

4.4. The magnitude and composition of the stimulus package

Ping Zhang, the head of the National Development and Reform Commission of China (NDRCC), introduced the composition of the 4 trillion yuan stimulus package in a press conference. According to Zhang's speech, the central government would invest 1.18 trillion yuan from the fourth quarter of 2008 till the end of 2010. This amount of investment was expected to induce 2.82 trillion yuan of additional investments from local governments and the private sector. The most detailed composition of the 4 trillion yuan of investments as announced by the central government is given in Table 4.

To estimate the effects of the stimulus package on the Chinese economy using input–output models, the government injections as assigned to broad categories in Table 4 should first be allocated to final demand for the products delivered by the industries that are present in the input–output table. Some categories (such as 400 billion yuan for item 1, “Housing and housing construction”) clearly relate to additional demand for the output of a specific industry, while other items are undisputedly referring to investment projects by a specific industry (e.g., 150 billion yuan for item 4, “Health, education and culture”). In the first case, we assign the category to final demand for the output of the construction industry; in the second case, we distribute the 150 billion yuan of the stimulus package category according to the investment structure of the industry concerned, using data from an investment matrix (which contains information about the investments by industry j in capital goods produced by industry i).¹⁶

We distribute the investment items as follows, in accordance with the investment progress report announced by the NDRCC.¹⁷ The progress report introduces more detailed investment projects in each investment item that have been carried out. This provides us additional information to distribute the investment items more appropriately. Item 1 (in Table 4) was fully attributed to final demand for output of the construction industry. The composition of investment item 2 is rather similar to the investment structure of the agriculture industry, so we split it into final demand for various outputs according to the investment structure of this industry in the investment matrix. Item 3 mainly consists of investments on physical infrastructure. The Ministry of Railways states that the part devoted to railway investment exceeds 1200 billion yuan,¹⁸ accounting for about 80% of item 3, and the shares of the other transportation investment projects are relatively small. Hence, we distribute approximately 80% of item 3 to transportation investment and the remaining part to investments in distribution network enhancement. According to the railway statistical bulletin

¹⁶ The most recent available investment matrix was published by NBS in 1997. We updated it to 2007, by a RAS procedure based on data for the row and column sums for 2007.

¹⁷ <http://finance.sina.com.cn/g/20090521/15016256643.shtml>

¹⁸ <http://finance.sina.com.cn/g/20081111/00035489448.shtml>

(Ministry of Railway, 2009), construction accounted for 86% of railway investments in 2009, and 14% was spent on transportation equipment. We allocate the railway investments in item 3 to the final demands for output of the *construction* industry and the *transport equipment* industry according to these proportions. We distributed the investments in distribution networks to final demands according to the investment structure of the *electricity and heating power production and supply* industry.

The allocation of the remaining investment categories to final demand for specific outputs of industries is relatively easy. We allocate item 4 according to the unweighted average investment structure of the *education* industry, the *health service* industry and the *culture* industry. Item 5 is treated in a similar vein, using the investment structure of the *water conservancy, environment and public accommodation management* industry. According to the progress report mentioned before, item 6 mainly focuses on improving high-tech processes and expanding high-tech industries. This requires constructing new plants or new production lines as well as introducing new equipment. Item 6 is thus

similar to the investment structure of high-tech manufacturing industries. However, we only have the investment structure of an aggregated manufacturing industry in the investment matrix. We therefore use the investment structure of the manufacturing industry to distribute this item to final demands. The last investment item mainly focuses on reconstructing houses and public facilities destroyed by the Wenchuan earthquake, so we allocate it entirely to the final demand for the output of the *construction* industry.

Some of the investment expenditures are on purchases of products from other countries. To take this into account, we adjust the final demand levels obtained by means of the procedures described above by multiplying these with the product-specific ratios of domestic demand over total demand, as obtained from the 2007 input–output table.

The estimated final demand vector that represents the initial effects of the stimulus package is given in Table 5, in the column labeled Δf^* .

Based on the data construction described in this section, the new semi-closed input–output model as given by Eq. (8) can be implemented for China.

Table 5
Impact of the 4 trillion yuan stimulus package on the value added of industries (unit: billion yuan).

Industry code (1)	α (2)	Δf^* (3)	Traditional model (4)	Semi-closed model (5)	New model (6)	Changes in endogenous consumption coefficient	
						– 5% (7)	– 10% (8)
1	0.045	0	78.8	254.2	151.0	113.8 (–24.6)	77.1 (–48.9)
2	0.000	0	76.2	88.0	80.2	78.1 (–2.6)	76.1 (–5.1)
3	0.000	0	83.2	98.6	88.2	85.7 (–2.9)	83.1 (–5.8)
4	0.000	0	42.3	44.7	43.1	42.7 (–1.0)	42.3 (–1.9)
5	0.000	0	45.2	47.2	46.0	45.6 (–0.8)	45.2 (–1.6)
6	0.067	0	26.1	98.5	55.7	40.5 (–27.4)	25.4 (–54.4)
7	0.002	0	10.8	22.2	16.1	13.4 (–16.8)	10.7 (–33.3)
8	0.028	0	10.6	28.5	19.4	14.9 (–23.4)	10.4 (–46.4)
9	0.003	7.9	29.7	34.2	31.7	30.7 (–3.1)	29.7 (–6.3)
10	0.001	0	23.3	33.5	26.6	24.9 (–6.3)	23.2 (–12.6)
11	0.001	0	58.4	68.4	61.5	59.9 (–2.6)	58.3 (–5.2)
12	0.010	0	111.4	146.4	125.5	118.2 (–5.8)	111.1 (–11.5)
13	0.001	0	238.9	244.2	240.7	239.8 (–0.4)	238.8 (–0.8)
14	0.000	0	246.0	258.9	250.4	248.1 (–0.9)	245.9 (–1.8)
15	0.002	13.4	56.8	62.1	58.8	57.8 (–1.8)	56.8 (–3.5)
16	0.000	209.7	129.4	137.2	132.0	130.7 (–1.0)	129.4 (–2.0)
17	0.003	226.3	88.1	100.2	90.5	89.3 (–1.4)	88.0 (–2.8)
18	0.008	91.2	60.0	67.8	63.0	61.5 (–2.5)	59.9 (–5.0)
19	0.002	12.5	13.3	18.1	14.4	13.8 (–3.8)	13.3 (–7.6)
20	0.000	6.0	4.6	5.3	4.8	4.7 (–2.4)	4.6 (–4.9)
21	0.003	8.8	10.5	15.5	11.8	11.1 (–5.6)	10.5 (–11.2)
22	0.000	0	58.8	63.9	60.6	59.7 (–1.5)	58.8 (–3.0)
23	0.007	0	130.4	160.8	140.5	135.3 (–3.7)	130.2 (–7.3)
24	0.001	0	1.9	3.0	2.2	2.1 (–8.0)	1.9 (–16.0)
25	0.001	0	4.8	7.7	5.7	5.3 (–8.2)	4.8 (–16.3)
26	0.003	3195.7	748.2	751.8	749.2	748.7 (–0.1)	748.2 (–0.1)
27	0.007	3.8	211.2	249.1	223.6	217.2 (–2.8)	210.9 (–5.7)
28	0.000	0	2.1	3.2	2.4	2.2 (–6.4)	2.1 (–12.7)
29	0.005	46.7	81.1	108.0	86.5	83.7 (–3.2)	81.0 (–6.4)
30	0.023	28.3	142.7	217.1	165.9	154.0 (–7.2)	142.2 (–14.3)
31	0.022	0	33.8	65.3	45.6	39.5 (–13.3)	33.6 (–26.4)
32	0.000	0	120.4	181.8	129.6	124.9 (–3.7)	120.2 (–7.3)
33	0.008	16.0	39.6	120.8	50.5	44.8 (–11.1)	39.3 (–22.1)
34	0.003	0	21.4	33.1	24.8	23.0 (–7.1)	21.3 (–14.1)
35	0.000	0	4.4	5.3	4.7	4.6 (–3.1)	4.4 (–6.3)
36	0.000	12.6	40.3	44.4	41.8	41.0 (–1.8)	40.2 (–3.7)
37	0.001	0	2.6	5.5	3.5	3.1 (–12.7)	2.6 (–25.2)
38	0.011	0	19.8	46.3	27.7	23.7 (–14.6)	19.7 (–29.1)
39	0.011	0	4.3	32.5	11.8	8.0 (–32.8)	4.1 (–65.2)
40	0.019	0	4.5	23.0	12.1	8.2 (–32.2)	4.4 (–64.1)
41	0.002	0	7.2	12.7	8.7	7.9 (–8.9)	7.2 (–17.8)
42	0.000	0	0.8	1.1	0.9	0.9 (–4.5)	0.8 (–8.9)
Sum		3878.7	3124.4	4010.3	3409.8	3262.8 (–4.3)	3117.6 (–8.6)
Total multiplier			0.781	1.003	0.852	0.816 (–4.3)	0.779 (–8.6)

Note: (1) See the industry classification in Appendix 2; (2) α represents the endogenous consumption coefficients for domestic products; (3) with regard to the values in columns (7) and (8), the terms in parentheses represent the differences relative to the values in the sixth column (in per cents); (4) the total multiplier is obtained as GDP caused by the stimulus package, divided by its value (4000 billion yuan).

5. The impact of the 4 trillion yuan stimulus package on the GDP of China

According to NBS (various years), GDP growth remained stable in 2009 (at 9.2%), but picked up considerably in 2010 (to almost 10.6%). In 2011, however, GDP growth slowed down again, to slightly more than 9%. These growth rates suggest that the stimulus package has had a short-run effect indeed, an observation also made by Fardoust et al. (2012). As discussed in the Introduction section, this stimulus package will have affected China's GDP in various ways. In this section, we estimate the combined short-run impacts of this stimulus package by using the model as outlined in the previous section.

Adjustments of prices and wages are usually slow in the short run, so we assume that the stimulus package did not lead the Chinese central bank to change the interest rate. Hence, we assume that the package did not affect investment funds of the private sector. This, and the fact that most investments in the package relate to public goods, are our main arguments for neglecting crowding-out of private investment in the short run.

Household consumption, however, has most likely been affected by this stimulus package. Higher incomes will have led to more consumption. On the other hand, however, households may have had expectations that the government would increase the tax rate in the future, to balance the fiscal deficit caused by this stimulus package. If so, they may have decided to save more to compensate for reduced future income.

In our first scenario, we estimate the short-term impact of this stimulus package on China's GDP by using the traditional input–output model, the semi-closed input–output model, and our new model, respectively. This gives an impression of the magnitude of the empirical differences. Second, we study the sensitivity of the short-term impact estimations to the assumption that model parameters are not affected by the policy change itself.

5.1. Value added impacts of the stimulus package and comparison of results

The additional value added of each industry caused by the stimulus package can be calculated by post-multiplying the respective value added multiplier matrices derived from the traditional input–output model, the semi-closed model and our new model ($\mathbf{M}(\omega)$, see Section 3.3) by $\Delta \mathbf{f}^*$. In all cases, this is done under the assumption that the model parameters are not affected by the stimulus package. For the model introduced in this paper, this implies that the endogenous consumption coefficients for 2009 and 2010 are assumed to have the same value as those in 2008. The value added effects are presented in Table 5.

Additional GDP driven by the 4 trillion yuan stimulus package as calculated on the basis of the traditional input–output model, the semi-closed input–output model and our new model amounts to 3124.4 billion yuan, 4010.3 billion yuan and 3409.8 billion yuan respectively. The estimated economy-wide value added multipliers are 0.781, 1.003 and 0.852 respectively. The multiplier for the traditional input–output model is smaller than the other two, because it does not take the linkages between demand and household into account. The economy-wide multiplier for the semi-closed model is obviously larger than that of our new model, due to the fact that it assumes that all consumption demand is endogenous. The total multipliers for the traditional input–output model and the new model are both smaller than 1 because of import leakage.

He et al. (2009) also estimated the multiplier of the 4 trillion yuan stimulus package, using the traditional open input–output model. Their estimated short-run economy-wide value added multiplier is 0.84, which is considerably larger than our multiplier for the traditional model. The difference is mainly caused by two reasons. First, their calculations are based on the input–output table in 2005, whereas ours are based on the input–output table for 2007, the

newest survey-based input–output table for China up to now. Two years after China's accession to the WTO in 2001, it started to import increasing proportions of its intermediate inputs. This tendency continued between 2005 and 2007, as a consequence of which the import leakage effects are higher in analyses based on the 2007 table. Second, the 'translations' of the information on investment levels per item in the stimulus package to additional final demand at industry level are different. The value added generated per unit final demand differs across industries, so different allocation procedures can lead to different GDP multipliers. Our allocation procedures are based on more additional information (such as the investment progress report and investment structures of industries) than the procedures adopted by He et al. (2009). Calculating the GDP multiplier with our traditional open input–output model and following the allocation procedures proposed by He et al. (2009), we arrive at a GDP multiplier of 0.85. This outcome is almost the same as He et al. (2009) report and which is larger than ours (0.78). This indicates that the difference is primarily due to a different translation of the stimulus package into final demand changes indeed.

Assuming that the saving behavior of households is not affected by the stimuli, Diao et al. (2012) arrived at an accumulated 75.4 trillion yuan effect on China's GDP over 2009–2015. The short-run economy-wide value added multiplier over 2009–2010 implied by their CGE model is 0.82. Despite the differences in modeling approach, this is comparable to the multiplier for our new semi-closed model (0.85). In Section 5.2, we will study the sensitivity of model outcomes with respect to the magnitude of the response of households to the stimuli in terms of their savings (which are assumed exogenous and fixed in Diao et al., 2012).

Turning to industry-level effects, the results for the new model show that the *construction* industry (26) has been affected most heavily by the stimulus package; its value added growth accounts for 22% of economy-wide total value added growth caused by the stimulus package. This result reflects the focus of the investment package on infrastructural projects. Hence, it does not come as a surprise that industries that have strong direct and indirect linkages with the *construction* industry—such as the *metals smelting and pressing* industry (14), the *nonmetal mineral products* industry (13), the *transport and warehousing* industry (27), the *wholesale and retail trade* industry (30), the *electricity and heating power production and supply* industry (23), the *finance and insurance* industry (32), and the *chemicals* industry (12)—are also strongly affected. The industry-level findings are also consistent with those of Diao et al. (2012).

For the Chinese economy as a whole, the impact as estimated by the new model is 9.1% larger than the impact estimated by means of the traditional input–output model (3410 vs. 3124 mln yuan). The differences at the level of industries show a lot of variation. The largest percentage differences are found for the *education* industry (39, 174% larger according to the new model), followed by the *health service* industry (40, 169%), the *food products manufacturing* industry (6, 113%) and *agriculture* (1, 92%). As indicated by the traditional input–output model, the *education* industry and the *health service* industry benefit little from the stimulus package via industry linkages (4.3 and 4.5 billion yuan). Instead, they have relatively high endogenous consumption coefficients (as indicated in the second column of Table 4) and thus benefit much from the stimulus package via induced household consumption. The dominant effect of induced household consumption causes the large percentage differences for these industries. The high induced household consumption demand caused by large endogenous consumption coefficients can also explain the large difference for *food products manufacturing* industry and *agriculture*. At the other end of the spectrum, the results for industries like *construction* (26), and the *nonmetal mineral products manufacturing* industry (13) are very insensitive to the choice of model; the differences in value added growth are less than 1%, indicating that these industries do not cater much to household consumption demand, neither directly nor indirectly.

In terms of absolute differences in impacts between the two models, *agriculture* (1, +72 mln yuan) and the *food products manufacturing* industry (6, +30 mln yuan) are the two industries with the most sizable differences. Together, these industries account for more than 35% of the difference in GDP increases as obtained with the two models.

5.2. Sensitivity analysis: model parameter changes due to the government intervention

The results presented in columns (4)–(6) of Table 5 are obtained under the assumption that all model parameters are insensitive to the stimulus package itself. The endogenous consumption parameters α , for example, have been assumed stable. As discussed before, however, a major expansionary fiscal policy measure (like the stimulus package) can cause changes in expectations regarding future tax rates. In this situation, the current household consumption might be negatively affected.¹⁹ To analyze the sensitivity of our results to phenomena like these, we compute results assuming that the endogenous consumption coefficients decrease by 5% and 10%, respectively. We recalculated the short-term impacts, using Eq. (14), which is derived from our new model.

$$\Delta \mathbf{v} = \bar{\mathbf{M}}(\omega) \Delta \mathbf{f}^* + [\bar{\mathbf{M}}(\omega) \mathbf{f}^* - \mathbf{M}(\omega) \mathbf{f}^*]. \quad (14)$$

In this equation, $\Delta \mathbf{f}^*$ is again the additional final demand vector and $\mathbf{f}^*$ is the exogenous final demand on domestic products in the framework constructed in Section 4. $\mathbf{M}(\omega)$ and $\bar{\mathbf{M}}(\omega)$ are the value added multiplier matrices before and after the changes in endogenous consumption coefficients respectively.

We find that with a 5%-decrease in the endogenous consumption coefficient for each industry, the GDP growth caused by the stimulus package is reduced by 4.3%, from 3409.8 billion yuan to 3262.8 billion yuan (and the total multiplier decreases from 0.852 to 0.816). If the endogenous consumption coefficients decrease by 10%, the total multiplier decreases to 0.779, which is slightly less than the economy-wide multiplier obtained using the traditional input–output model. This implies that in this situation, the negative effect of the stimulus package on the current household consumption offsets the positive effect of the current income to household consumption linkage. If the Chinese government would have feared sizable changes in household expectations regarding its fiscal policies in the future, it would have acted wisely if it would have simultaneously announced policy measures with a favorable impact on its future fiscal situation.

6. Conclusions

In this paper we proposed a new semi-closed input–output model to estimate the impact (in terms of value added growth in Chinese industries) of fiscal stimuli. In previous semi-closed input–output models, household consumption is assumed to be fully endogenous, in the sense that current consumption is completely driven by income. This is not consistent with several strands of consumption theory, and we argued that it could well overestimate the effects of expansionary fiscal policies. Our new model does not suffer from this drawback, since it distinguishes between an endogenous and an exogenous part of household consumption. The first type of consumption is determined by the current household income, and the latter by other factors.

As an illustration of our new model, we estimated the short-run effects of the 4 trillion yuan stimulus package on China's GDP, for two scenarios. We first calculated the impacts using the traditional open input–

output model, the semi-closed input–output model, and our new model, assuming that the model parameters were not affected by the stimulus package. Our estimated impacts are, as expected, higher than those in the traditional input–output model (in which all household consumption is exogenous), and smaller than the impacts obtained by the semi-closed input–output model (in which all household consumption is endogenous). For the new model, we estimate a GDP multiplier of 0.852 (the traditional input–output model yields a GDP multiplier equal to 0.781). This multiplier is lower than 1, because part of the stimulus package will induce additional imports, which do not generate Chinese value added. The results are in line with the actual changes in Chinese GDP after the stimulus package was introduced and also compares well with estimates obtained by means of rather different types of models.

To find indications for the sensitivity of the estimated impacts to the assumption of stable model parameters, we also applied the new model to a scenario in which households decide to decrease their endogenous consumption, because they feel that the government expenditures will be compensated by higher taxes at a later stage (“so-called Ricardian equivalence”). Our results suggest that a reduction of the endogenous consumption coefficients of 10% (for all consumption categories) as a consequence of this phenomenon would lead to a GDP multiplier that is even lower than that of the traditional input–output model. This indicates that model calculations like ours could be a valuable tool when designing policies. If governments believe that endogenous consumption parameters are very sensitive to large changes in a certain fiscal policy, they may want to anticipate this effect and adapt the policy.

Our model could also be used to estimate the effects of other shocks. For instance, in 2013 the Chinese government launched a twofold development strategy to help China integrate further in the world economy. It consists of a land-based part called the “New Silk Road Economic Belt” and an oceangoing part called the “21st-century Maritime Silk Road”. It can be seen as an export promotion policy combined with massive infrastructural projects. A new network of motorways, railroads, and ports are envisaged, part of which will be on Chinese territory. The strategy also focuses on increasing China's exports for industries with overproduction, such as steel manufacturing. Once this initiative is “translated” in specific industry-level investment and export targets, our new approach would allow for estimating its effects on the Chinese economy. Using social accounting matrices, our modeling approach could relatively easily be extended to quantify the effects of fiscal stimuli on income inequality across various household categories.

Acknowledgments

We would like to thank the associate editor Russell Smyth and the anonymous reviewer for their useful comments. Quanrun Chen gratefully acknowledges financial support by the National Natural Science Foundation of China (Grant Numbers 71201162, 71125005 and 61273208).

Appendix 1. Using the Kalman filter to estimate the time varying parameter model

The Kalman filter (see Harvey, 1987; Hamilton, 1994) is a recursive algorithm to obtain estimates for the parameters of interest in period t , based on the values of these parameters (“the state”) at $t - 1$ and observations for the model variables at t . The technique has been successfully applied to address empirical economic issues that require the use of time varying parameter (TVP) models and unobserved component models. Suppose that a univariate TVP model is specified with a measurement equation

$$y_t = \mathbf{x}_t' \boldsymbol{\beta} + \mathbf{z}_t' \boldsymbol{\alpha}_t + \xi_t \quad t = 1, 2, \dots, T$$

¹⁹ See “new Keynesian” models used for fiscal policy analysis (e.g. Horvath, 2009; Cogan et al., 2010).

and a transition equation

$$\alpha_t = T\alpha_{t-1} + \eta_t \quad t = 1, 2, \dots, T.$$

y_t is the dependent variable observed at time t ; α_t is a state vector ($m \times 1$) with the time varying parameters of interest; z_t is a vector ($m \times 1$) with the observations at t of variables that affect the dependent variable in a way that is not stable over time; x_t is a vector ($n \times 1$) with observations at t of explanatory variables for which the coefficients vector β ($n \times 1$) is supposed to be time-invariant. T is a fixed matrix ($m \times m$) which is specified based on prior information; the disturbances ξ_t and η_t are white noise, with zero means and (co)variance (matrices) h and Q respectively. ξ_t and η_t are assumed to be mutually serially independent. For the purpose of the Kalman filter, β , T , h and Q are regarded as being fixed and known. These parameters can be estimated from the data using maximum likelihood estimation.

Let α_{t-1} be the minimum mean squared error (MMSE) estimator of α_{t-1} based on all the information up to time $t-1$, and let P_{t-1} be the mean squared error matrix of α_{t-1} . Given α_{t-1} and P_{t-1} at time $t-1$, the MMSE estimator of α_t and its mean squared error matrix are:

$$\hat{\alpha}_{t|t-1} = T\hat{\alpha}_{t-1} \quad (A1.1)$$

$$P_{t|t-1} = TP_{t-1}T' + Q. \quad (A1.2)$$

When a new observation for y at time t is available, the estimator and its mean squared error matrix can be updated according to the following formulas:

$$\hat{\alpha}_t = \hat{\alpha}_{t|t-1} + P_{t|t-1}z_t'(y_t - x_t'\beta - z_t'\hat{\alpha}_{t|t-1}) / (z_t'P_{t|t-1}z_t + h) \quad (A1.3)$$

$$P_t = P_{t|t-1} - P_{t|t-1}z_t'z_tP_{t|t-1} / (z_t'P_{t|t-1}z_t + h). \quad (A1.4)$$

Eqs. (A1.1) and (A1.2) are often called the “prediction equations”, and Eqs. (A1.3) and (A1.4) are frequently referred to as “updating equations”. Together, they make up the Kalman filter.

The Kalman filter yields the MMSE estimator of the state vector (α_t) based on the available information up to time t only. In this paper, we further used all the information in the sample (T observations) to obtain smoothed estimates of the state vector $\alpha_{t|T}$ by fixed-interval smoothing. The fixed interval smoothing is a recursive process (see Harvey, 1987). It starts with the final Kalman filter estimates α_T and P_T and then applies the smoothing equations $\hat{\alpha}_{t|T} = \hat{\alpha}_t + P_t^*(\hat{\alpha}_{t+1|T} - T\hat{\alpha}_t)$ and $P_{t|T} = P_t + P_t^*(P_{t+1|T} - P_{t+1|t})P_t^*$, with $P_t^* = P_tT'P_{t+1|t}^{-1}$, $t = T-1, T-2, \dots, 1$. Finally, $\hat{\alpha}_{T|T} = \hat{\alpha}_T$; $P_{T|T} = P_T$.

Appendix 2. Bridge matrix for the eight broad consumption categories in the household survey data in the China Statistical Yearbook and the forty-two industries in the 2007 China input–output table

Industries	F	C	H	HFS	HM	TC	ECR	M
1. Agriculture	0.333	0	0	0	0	0	0	0
2. Coal mining, washing and processing	0	0	0.014	0	0	0	0	0
3. Crude petroleum and natural gas products	0	0	0	0	0	0	0	0
4. Metal ore mining	0	0	0	0	0	0	0	0
5. Non-ferrous mineral mining	0	0	0	0	0	0	0	0
6. Manufacture of food products and tobacco processing	0.473	0	0	0	0.144	0	0	0
7. Textile goods	0	0.048	0	0.009	0.002	0	0	0
8. Wearing apparel, leather, furs, down and related products	0	0.631	0	0.121	0	0	0	0
9. Sawmills and furniture	0	0	0	0.105	0	0	0	0
10. Paper and products, printing and record medium reproduction	0	0	0	0	0	0	0.039	0
11. Petroleum processing, coking and nuclear fuel processing	0	0	0	0	0	0.067	0	0
12. Chemicals	0	0	0	0.315	0.055	0	0	0.167
13. Nonmetal mineral products	0	0	0.024	0.005	0	0	0	0
14. Metals smelting and pressing	0	0	0	0	0	0	0	0
15. Metal products	0	0	0	0.083	0	0	0	0
16. Common and special equipment	0	0	0	0	0.011	0	0	0
17. Transport equipment	0	0	0	0	0	0.222	0	0
18. Electric equipment and machinery	0	0	0	0.300	0	0	0	0.159
19. Telecommunication equipment, computer and other electronic equipment	0	0	0	0	0	0.121	0.057	0
20. Instruments, meters, cultural and office machinery	0	0	0	0	0	0	0.016	0.003
21. Art and craft and other manufacturing products	0	0	0	0	0	0	0	0.491
22. Scrap and waste	0	0	0	0	0	0	0	0
23. Electricity and heating power production and supply	0	0	0.222	0	0	0	0	0
24. Gas production and supply	0	0	0.030	0	0	0	0	0
25. Water production and supply	0	0	0.030	0	0	0	0	0
26. Construction	0	0	0.088	0	0	0	0	0
27. Transport and warehousing	0.006	0.053	0.055	0.010	0.002	0.067	0.031	0.005
28. Post	0	0	0	0	0	0.005	0	0
29. Information communication, computer service and software	0	0	0	0	0	0.185	0.087	0
30. Wholesale and retail trade	0.019	0.176	0.181	0.034	0.006	0.219	0.103	0.018
31. Accommodation, eating and drinking places	0.159	0	0	0	0	0	0	0.148
32. Finance and insurance	0	0	0	0	0	0	0	0
33. Real estate	0	0	0.262	0	0	0	0	0
34. Renting and commercial service	0	0	0	0	0	0	0.114	0
35. Research and development	0	0	0	0	0	0	0	0
36. General technical services	0	0	0	0	0	0	0	0
37. Water conservancy, environment, and public accommodation management	0	0	0	0	0	0	0.027	0
38. Household service and other social services	0.010	0.091	0.093	0.018	0.003	0.113	0.053	0.009
39. Education	0	0	0	0	0	0	0.401	0
40. Health service, social guarantee and social welfare	0	0	0	0	0.779	0	0	0
41. Culture, sports and amusements	0	0	0	0	0	0	0.071	0
42. Public management and social administration	0	0	0	0	0	0	0	0

Note: F = food; C = clothing; H = housing; HFS = home equipment, facilities and services; HM = health and medical care; TC = transportation and communication; ECR = education, cultural and recreational services; M = miscellaneous goods and services.

References

- Ando, A., Modigliani, F., 1963. The life cycle hypothesis of saving: aggregate implications and tests. *Am. Econ. Rev.* 53, 55–84.
- Attanasio, O.P., Weber, G., 1993. Consumption growth, the interest rate and aggregation. *Rev. Econ. Stud.* 60, 631–649.
- Barnett, W.A., Serletis, A., 2008. Consumer preferences and demand systems. *J. Econ.* 147, 210–224.
- Batey, P., Weeks, M.J., 1989. The effect of household disaggregation in extended input–output models. In: Miller, R.E., Polenske, K.R., Rose, A.Z. (Eds.), *Frontiers of Input–Output Analysis*. Oxford University Press, New York, pp. 119–133.
- Batey, P., Madden, M., Weeks, M.J., 1987. Household income and expenditure in extended input–output models: a comparative theoretical and empirical analysis. *J. Reg. Sci.* 27, 341–356.
- Burdekin, R.C., Weidenmier, M.D., 2015. Assessing the impact of the Chinese stimulus package at home and abroad: a damp squib? *China Econ. Rev.* 33, 137–162.
- Carroll, C.D., 1994. How does future income affect current consumption. *Q. J. Econ.* 109, 111–147.
- Chen, Q., Dietzenbacher, E., Los, B., 2015. Structural decomposition analyses: the differences between applying the semi-closed and the open input–output model. *Environ. Plan. A* 47, 1713–1735.
- Clements, K.W., Selvanathan, S., 1994. Understanding consumption patterns. *Empir. Econ.* 19, 69–110.
- Clements, K.W., Wu, Y., Zhang, J., 2006. Comparing international consumption patterns. *Empir. Econ.* 31, 1–30.
- Cloutier, M.L., Thomasin, P.J., 1994. Closing the Canadian input–output model: homogeneous vs non-homogeneous household sector specifications. *Econ. Syst. Res.* 6, 397–414.
- Cogan, J.F., Cwik, T., Taylor, J.B., Wieland, V., 2010. New Keynesian versus old Keynesian government spending multipliers. *J. Econ. Dyn. Control.* 34, 281–295.
- Dennis, R., 2009. Consumption habits in a new Keynesian business cycle model. *J. Money Credit Bank.* 41, 1015–1030.
- Diao, X., Zhang, Y., Chen, K.Z., 2012. The global recession and China's stimulus package: a general equilibrium assessment of country level impacts. *China Econ. Rev.* 23, 1–17.
- Dietzenbacher, E., Günlük-Şenesen, G., 2003. Demand-pull and cost-push effects on labor income in Turkey, 1973–90. *Environ. Plan. A* 35, 1785–1807.
- Dietzenbacher, E., Miller, R.E., 2009. RAS-ing the transactions or the coefficients: it makes no difference. *J. Reg. Sci.* 49, 555–566.
- Dietzenbacher, E., Los, B., Stehrer, R., Timmer, M.P., de Vries, G.J., 2013. The construction of world input–output tables in the WIOD project. *Econ. Syst. Res.* 25, 71–98.
- Duesenberry, J., 1949. *Income, Saving and the Theory of Consumer Behavior*. Harvard University Press, London.
- Engle, R.F., Watson, M.W., 1987. The Kalman filter: applications to forecasting and rational expectations models. In: Bewley, T.F. (Ed.), *Advances in Econometrics*. Cambridge University Press, Cambridge, pp. 245–283.
- Erlandsen, S., Nymoen, R., 2008. Consumption and population age structure. *J. Popul. Econ.* 21, 505–520.
- Fardoust, S., Lin, J.Y., Luo, X., 2012. Demystifying China's fiscal stimulus. *World Bank Policy Research Working Paper*, p. 6221.
- Friedman, M., 1957. *A Theory of the Consumption Function*. Princeton University Press, New Jersey.
- Golan, A., Judge, G., Robinson, S., 1994. Recovering information from incomplete or partial multisectoral economic data. *Rev. Econ. Stat.* 76, 541–549.
- Hall, R.E., 1978. Stochastic implications of the life cycle-permanent income hypothesis: theory and evidence. *J. Polit. Econ.* 86, 971–987.
- Hamilton, J.D., 1994. *Time Series Analysis*. Princeton University Press, New Jersey.
- Harvey, A.C., 1987. Application of the Kalman filter in econometrics. In: Bewley, T.F. (Ed.), *Advances in Econometrics*. Cambridge University Press, Cambridge, pp. 285–313.
- He, D., Zhang, Z., Zhang, W., 2009. How large will be the effect of China's fiscal stimulus package on output and employment. *Pac. Econ. Rev.* 14, 730–744.
- Hong, C., Li, J., 2015. On measuring the effects of fiscal policy in global financial crisis: evidence from an export-oriented island economy. *Econ. Model.* 46, 412–415.
- Horvath, M., 2009. The effect of government spending shocks on consumption under optimal stabilization. *Eur. Econ. Rev.* 53, 815–829.
- Karagiannis, G., Velentzas, K., 2004. Decomposition analysis of consumers' demand changes: an application to Greek consumption data. *Appl. Econ.* 36, 497–504.
- Luengo-Prado, M.J., Sørensen, B.E., 2008. What can explain excess smoothness and sensitivity of state-level consumption. *Rev. Econ. Stat.* 90, 65–80.
- Luptacik, M., Böhm, B., 1999. A consistent formulation of the Leontief pollution model. *Econ. Syst. Res.* 11, 263–276.
- Lyons, S., Mayor, K., Tol, R.S.J., 2009. Convergence of consumption patterns during macro-economic transition: a model of demand in Ireland and the OECD. *Econ. Model.* 26, 702–714.
- Mankiw, N.G., 2010. *Macroeconomics*. seventh ed. Worth Publishers, New York.
- McKissack, A., Xu, J.Y., 2011. Chinese macroeconomic management through the crisis and beyond. *Asian-Pac. Econ. Lit.* 25, 43–55.
- Miller, R.E., Blair, P.D., 2009. *Input–Output Analysis: Foundations and Extensions*. second ed. Cambridge University Press, New York.
- Ministry of Railways, 2009. *Railway Statistical Bulletin 2009*. <http://www.coalchina.org.cn/page/info.jsp?id=19852>.
- Miyazawa, K., 1976. *Input–Output Analysis and the Structure of Income Distribution*. Springer-Verlag Press, Berlin.
- Muellbauer, J., Lattimore, R., 1999. The consumption function: a theoretical and empirical overview. In: Pesaran, M.H., Wickens, M. (Eds.), *Handbook of Applied Econometrics*. Blackwell Press, Oxford, pp. 221–311.
- National Bureau of Statistics (NBS) (various years) *China Statistical Year Book*. Beijing, China Statistics Press.
- Rose, A., 1995. Input–output economics and computable general equilibrium models. *Struct. Chang. Econ. Dyn.* 6, 295–304.
- Wakabayashi, M., Hewings, G.J.D., 2007. Life-cycle changes in consumption behavior: age-specific and regional variations. *J. Reg. Sci.* 47, 315–337.
- Whalley, J., Zhao, X., 2013. The relative importance of the Chinese stimulus package and tax stabilization during the 2008 financial crisis. *Appl. Econ. Lett.* 20, 682–686.
- Yang, C., Chen, X., Xu, J., 2008. A method to optimize gross fixed capital investments for water conservancy in China. *Econ. Syst. Res.* 20, 151–172.