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

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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.

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

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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:

$$\begin{bmatrix} \mathbf{A} & \overline{\boldsymbol{\alpha}} \\ \mathbf{w}' & 0 \end{bmatrix} \begin{bmatrix} \mathbf{x} \\ x_{n+1} \end{bmatrix} + \begin{bmatrix} \mathbf{f}+\mathbf{e} \\ h \end{bmatrix} = \begin{bmatrix} \mathbf{x} \\ x_{n+1} \end{bmatrix}. \tag{1}$$

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, $\overline{\boldsymbol{\alpha}} = (\overline{\alpha}_i)_{n\times 1}$ 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 $\overline{\alpha}_i$ are defined as $\overline{\alpha}_i = c_i/x_{n+1}$, 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 as 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.