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Simulating the U.S. Recession With or Without the Obama Package: The Role of Excess Capacity

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Abstract

Simulations with dynamic, single-country, CGE models typically imply that reductions in domestic demand, e.g. a cut in investment, generate increases in exports and reductions in imports facilitated by real depreciation. However, currently in the U.S. a large reduction in investment is occurring simultaneously with a contraction in exports and little movement in the real exchange rate. We show that to describe this situation it is necessary to drop the standard CGE assumption that capital is always fully employed in every industry. After introducing an excess-capacity specification, we simulate the U.S. recession with and without the Obama stimulus package.

Key words: U.S. recession; CGE modelling; excess capacity; sticky rents; mark-up pricing.

JEL codes: C68; D50; E30; E60.

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1. Introduction

This paper is concerned with the application of micro-based macroeconomic models to the analysis of recessions. These models incorporate optimizing behaviour by economic agents such as households, producers, exporters, importers and investors. Such models commonly use production functions with labour and materials treated as variable inputs. By contrast, capital is treated as fixed in the short run, with the level of capital input determined by past investments. This treatment of capital rests on the assumption of continuous full-capacity utilization. With this assumption, we find that it is not possible to replicate the main features of the sort of downturn currently being experienced by the Unites States. Our focus will be computable general equilibrium (CGE) models. However, the issues that we identify are also of relevance to dynamic, stochastic general equilibrium (DSGE) models.

To illustrate our argument, we use USAGE, a dynamic CGE model, to look at the U.S. economy in 2008-9 and beyond. We start with a bland (no recession) baseline. Then we impose on USAGE the observed and anticipated macro features of the current U.S. recession as perturbations from the baseline. This is done by exogenously moving macro aggregates from their baseline paths to recession paths and allowing the model to endogenously compute movements in shift variables representing investor confidence, consumer confidence and world trading conditions. We find that it is possible to generate a realistic picture of the U.S. recession (realistic values for shift variables) only when we allow for excess capacity. This means that we need to drop the standard assumption that capital rental rates adjust in each industry so that capital is fully used.

Since we take observed and anticipated features of the recession as given, the question arises as to what the model gives us. There are three contributions. First, with the shift variables in place, USAGE generates results for a broad range of disaggregated variables covering industries, regions and occupations. Second, USAGE offers a convenient way of simulating recovery from a recession as a gradual return of the shift variables to their baseline paths. Third, USAGE provides a framework for analyzing recession-mitigating strategies such as the Obama package.

The rest of the paper is organized as follows. Section 2 gives necessary background on USAGE simulations and treatments of labour and capital. USAGE is quite conventional in these

respects and consequently our methodological findings are broadly applicable. Section 3 reports results from three recession simulations undertaken with standard assumptions. All of these simulations prove to be unsatisfactory. As shown in Section 4, the problem is the assumption of full capacity utilization. Section 5 sets out a specification that allows for excess capacity with sticky adjustment of capital rental rates. Sections 6 and 7 apply the excess-capacity specification in USAGE simulations of the U.S. recession and recovery without the Obama stimulus package and then with the package. Concluding remarks are in section 8.

2. USAGE: a dynamic CGE model of the U.S.

USAGE is a dynamic CGE model of the U.S. developed in collaboration with the U.S. International Trade Commission[1]. Its theoretical structure is similar to that of Australia's MONASH model, Dixon and Rimmer (2002).

A USAGE simulation of the effects of a shock to the economy (e.g. a credit crisis) requires two runs of the model: a baseline run and a perturbation run. The baseline is intended to be a plausible forecast while the perturbation run generates deviations away from the baseline caused by the shocks under consideration. For this paper the most important features of the theory underlying perturbation runs concern labour and capital markets.

2.1 Labour market

In perturbation runs we assume that wage rates adjust in a sticky fashion away from their baseline path according to:

$$\left\{\frac{W(t)}{W_b(t)}-1\right\} = \left\{\frac{W(t-1)}{W_b(t-1)}-1\right\} + \alpha_1\left\{\frac{L(t)}{L_b(t)}-1\right\}. \qquad (1)$$

In this equation the subscript b indicates a baseline value, that is, a value in the run without the policy or other shocks (in this case recession shocks) under consideration. $W_b(t)$ and $L_b(t)$ are the wage rate and the level of employment in year t in the baseline. W(t) and L(t) are the wage rate and the level of employment in year t in the perturbation run, that is the run with the shocks. α_1 is a positive coefficient.

[1] Prominent applications of USAGE by the U.S. International Trade Commission include USITC (2004, 2007 and 2009).

Under (1), we assume in perturbation runs that the deviation in the wage rate from its baseline level increases at a rate which is proportional to the deviation in aggregate hours of employment from its baseline level.[2] The coefficient of proportionality (α_1) is chosen so that the employment effects of a shock to the economy are largely eliminated after 5 years. This labour market assumption is consistent with conventional macro-economic modelling in which the NAIRU is exogenous. It is also compatible with search models and efficiency-wage theory, see for example, Bohringer *et al*. (2005) and Layard *et al.* (1994, pp. 33-45). In search models, increases in employment and resulting reductions in the unemployment rate, generate decreases in the value of having a job relative to the value of not having a job, thereby emboldening workers to demand higher wage rates. In efficiency-wage theory, employers offer wage rates that optimize worker effort per dollar of wage cost. The theory suggests that the effort-optimizing wage rate rises when there is an increase in employment and a consequent temporary decrease in unemployment.

In most applications of USAGE, (1) has been applied with W being the real wage (wage divided by the consumer price index). In this paper we also use a version in which W is the nominal wage ($ per hour). The distinction between real and nominal wage stickiness is immaterial when consumer prices are fixed (treated as the numeraire). However, as we will see in sections 3 and 4, we allow consumer prices to be determined endogenously.

2.2 Capital market

As is standard for dynamic CGE and for DSGE models, in USAGE capital in industry j accumulates according to:

$$K(j,t+1) = K(j,t)*[1-D(j)] + I(j,t) \qquad (2)$$

where

K(j,t) is the quantity of capital available for use in industry j during year t;
I(j,t) is the quantity of new capital created for industry j during year t; and
D(j) is the rate of depreciation, treated as a parameter.

The rate of growth of capital, and consequently investment, in industry j in each year is determined as an increasing function of the expected rate of return [EROR(j,t)]:

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[2] In (1) we assume that the shocks under consideration do not affect labour supply.

$$\frac{I(j,t)}{K(j,t)} - D(j) = f_j\left[EROR(j,t),\ H(j,t)\right] \qquad (3)$$

Also included on the right hand side of (3) is a shift variable [H(j,t)] that can be used to simulate the effects of changes in confidence that affect the amount of investment undertaken at any given level of EROR(j,t).

In USAGE and almost all other dynamic models, the critical variable in the specification of EROR(j,t) is the current rental rate on capital [Q(j,t)]. This is determined so as to equate demand for capital with available capital. For year-on-year simulations, we assume that capital cannot be transferred between industries (the putty/clay assumption). Thus, in standard applications of USAGE we have equations of the form:

$$EROR(j,t) = g_j\left[Q(j,t), ...\right] \quad \text{, and} \qquad (4)$$

$$Q(j,t) = n_j\left[K(j,t), ...\right] \quad , \qquad (5)$$

where g_j is an increasing function that relates the expected rate of return on investment in industry j to the current rental rate on j's capital, and n_j is a decreasing function (reflecting decreasing marginal productivity of capital) that relates the demand for capital in industry j to it rental rate.

Under (2) to (5) an increase in demand for industry j's products in year t causes an increase in demand for capital in industry j. But the supply of capital cannot be increased immediately. The supply available for use in year t is predetermined at K(j,t). The increase in demand for capital is choked off [via (5)] by an increase in the rental rate Q(j,t). This increases expected rates of return [via (4)] and investment [via (3)] leading to increased capital availability in future years [via (2)].

3. Three failed experiments

The left hand panel of Table 1 shows our 2008-9 forecasts made in 2007 for the expenditure side of GDP. These forecasts were based on a variety of official sources including Bureau of Labor Statistics (2007) and U.S. Department of Agriculture (2007). By early 2009 it was apparent that in the absence of decisive policy action, the actual outcomes for 2008-9 were

Table 1. Forecast growth rates (%) for expenditure components of real GDP

	Forecast made in 2007 (pre-recession)		Forecast made in early 2009 (full-recession)	
	2008	2009	2008	2009
Private consumption	3.19	3.19	0.40	-3.50
Public consumption	1.97	1.97	1.97	1.97
Investment	5.33	5.33	-6.60	-25.00
Exports	6.03	6.03	6.40	-10.00
Imports	5.58	5.58	-3.40	-18.00
GDP	3.29	3.30	0.65	-4.68

likely to be in line with the recession scenario in the right hand panel, see for example U.S. Department of Agriculture (2009) and OECD (2009).[3]

In this section we adopt the figures in the left hand panel as the baseline. Then we use USAGE to answer the question of how the economy could move from the baseline to a situation like the full recession scenario in the right hand panel. We calculate implied changes in variables reflecting investor and consumer confidence, preferences for imported goods versus domestic goods, and the positions of world demand curves for U.S. exports.

In moving from the baseline towards to the full recession scenario we started by assuming that the main change was a reduction in investor confidence brought on by a collapse in the availability of credit. To reflect this we ran a recession simulation, RS-1, in which shocks were imposed to take investment growth from its baseline value of 5.33 per cent in the left hand panel of Table 1 to the values in the right hand panel (-6.60 and -25.00). To allow us to impose these exogenous investment shocks, we endogenized shift variables in the functions that relate investment to expected rates of return on capital [that is, we endogenized the H(j,t)s in (3)]. As can be seen from line 10 in the first panel in Table 2, the shift variables moved by 0.66 and 2.77 from their baseline values. This means that if in the baseline an expected rate of return of 4 per

[3] The forecasts in these last two sources anticipate a stimulus package. Consequently, they are not as gloomy as those shown in the right hand panel of Table 1 which are our projections based on the assumption of no stimulus package.

cent was required to support capital growth for an industry of 3 per cent, then in RS-1 expected rates of return of 4.66 and 6.77 per cent are required to support capital growth of 3 per cent.

Reductions in investment growth explained by increased required rates of return go some of the way towards moving the economy from the bland baseline in the left hand panel of Table 1 to the full recession in the right hand panel. Comparing Table 1 and the top part of Table 2, we see that RS-1 generates reductions in growth rates for: consumption (down from 3.19 per cent in the baseline to 1.99 and 0.04 per cent); imports (5.58 to -0.15 and -5.89); and GDP (3.29 to 2.35 and 0.67). However, export growth is strongly increased (up from 6.03 per cent in the baseline to 16.65 and 27.73 per cent).

In recession simulation RS-2 we impose export growth rates from the full recession scenario in the right hand panel of Table 1. We continue to impose the recession growth rates for investment. To exogenize aggregate export growth we endogenize a uniform horizontal movement in the demand curve for each U.S. export. As indicated in Table 2 (row 12, panel 2), the anticipated downturn in export growth can be explained by shifts in export demand curves implying losses in sales of 21.60 and 69.61 per cent at any given foreign currency price. Again comparing Tables 1 and 2, we see that the cuts in export growth in RS-2 move us closer to the full recession scenario. Consumption growth rates (row 1) are quite close to those in the full recession scenario and import growth rates (row 5) are a little low but not clearly unrealistic. However, there are two obviously unsatisfactory features of the RS-2 results: they imply huge real devaluations (12.60 and 58.38 per cent, row 21, panel 2) relative to the baseline, and huge declines in the terms of trade (7.96 and 28.94 per cent, row 19). Neither devaluation nor terms-of-trade decline of anything like these magnitudes are part of the current U.S. experience.

In RS-3 we set the movements in consumption and imports at their values in the full recession scenario by endogenizing the average propensity to consume (row 8, panel 3) and a twist in preferences between domestic and imported commodities (row 14, panel 3). More importantly, we fixed the movements in the terms of trade to be the same as in the baseline. Fixing the terms of trade in this way seems realistic: with a world-wide recession there is no reason to assume that U.S. export prices should be affected in a significantly different way from U.S. import prices. In fixing the terms of trade, we endogenize a shift variable affecting foreign currency import prices (row 20).

Table 2. Recession simulations: three failures and a success

		RS-1: Reduced investor confidence			RS-2: Reduced investor confidence & export demand			RS-3: Recession growth for C, I, G, X and M Full capacity utilization			RS-4: Recession growth for C, I, G, X and M Excess capacity		
		[a]	2008	2009	[a]	2008	2009	[a]	2008	2009	[a]	2008	2009
		Year-on-year growth rates (per cent)											
1	Real private consumption	N	1.99	0.04	N	1.28	-3.29	X	0.40	-3.50	X	0.40	-3.50
2	Real public consumption	X	1.97	1.97	X	1.97	1.97	X	1.97	1.97	X	1.97	1.97
3	Real investment	X	-6.60	-25.00	X	-6.60	-25.00	X	-6.60	-25.00	X	-6.60	-25.00
4	Real exports	N	16.65	27.73	X	6.40	-10.00	X	6.40	-10.00	X	6.40	-10.00
5	Real imports	N	-0.15	-5.89	N	-6.75	-28.83	X	-3.40	-18.00	X	-3.40	-18.00
6	Real GDP	N	2.35	0.67	N	1.96	-1.73	N	0.65	-4.68	N	0.65	-4.68
		Percentage deviations from baseline values											
7	Real private consumption	N	-1.16	-4.19	N	-1.86	-8.03	X	-2.71	-9.02	X	-2.71	-9.02
8	Average propensity to consume	X	0.00	0.00	X	0.00	0.00	N	-2.04	-5.10	N	-0.63	-0.85
9	Real investment	X	-11.33	-36.86	X	-11.33	-36.86	X	-11.33	-36.86	X	-11.33	-36.86
10	Investor confidence shift[b]	N	0.66	2.77	N	0.34	1.07	N	-0.19	-0.04	N	0.72	1.64
11	Real exports	N	10.01	32.53	X	0.35	-14.83	X	0.35	-14.83	X	0.35	-14.83
12	Horizontal export demand shift[c]	X	0.00	0.00	N	-21.60	-69.61	N	-12.66	-46.54	N	-0.87	-20.57
13	Real imports	N	-5.42	-15.70	N	-11.68	-40.46	X	-8.50	-28.94	X	-8.50	-28.94

Table 2continues …

Table 2 continues

		RS-1			RS-2			RS-3			RS-4		
		[a]	2008	2009	[a]	2008	2009	[a]	2008	2009	[a]	2008	2009
		Percentage deviations from baseline values											
14	Import/domestic twist[d]	X	0.00	0.00	X	0.00	0.00	N	-13.80	-42.60	N	-16.03	-46.43
15	Real GDP	N	-0.90	-3.42	N	-1.29	-6.09	N	-2.55	-10.07	N	-2.55	-10.07
16	Employment, hours	N	-1.20	-4.29	N	-1.63	-7.32	N	-3.37	-12.48	N	-2.59	-10.32
17	Shift, sticky real wages[e]	X	0.00	0.00	X	0.00	0.00	N	5.79	12.19	N	0.69	1.96
18	Shift, sticky nominal wages[f]	N	-4.98	-8.11	N	-9.81	-22.51	X	0.00	0.00	X	0.00	0.00
19	Terms of trade	N	-3.42	-9.64	N	-7.96	-28.94	X	0.00	0.00	X	0.00	0.00
20	Import price shift	X	0.00	0.00	X	0.00	0.00	N	-4.70	-14.51	N	-0.60	-2.54
21	Real exchange rate[g]	N	-6.06	-17.79	N	-12.60	-58.38	N	-0.18	0.70	N	-0.12	-0.10
22	Capital in use	N[h]	0.00	-0.85	N[h]	0.00	-0.85	N[h]	0.00	-0.85	N[h]	-2.39	-8.90
23	Capital in existence	X[i]	0.00	-0.85	X[i]	0.00	-0.85	X[i]	0.00	-0.85	X[i]	0.00	-0.85
24	Real wage rate	N	-0.46	-1.68	N	-0.60	-2.29	N	4.76	14.69	N	-0.17	-0.25

[a] N indicates endogenous and X indicates exogenous. [b] Shift in percentage expected rate of return required to support any given level of capital growth. [c] Increase in quantity of exports at any given foreign-currency price. [d] Twist in preferences for imported (M) relative to domestic (D) goods: increase in M/D that is independent of changes in the price ratio. [e] If this variable is exogenous then stickiness in wage adjustment is imposed in real terms. [f] If this variable is exogenous then stickiness in wage adjustment is imposed in nominal terms. [g] See footnote 6. [h] In RS-1 to RS-3, capital in use moves with capital in existence. In RS-4 it is determined via sticky rental adjustment. [i] Capital in existence is predetermined in each year.

Another change in RS-3 relative to RS-2 is in the treatment of wages. In RS-2 we implemented (1) with W being the average *real* wage. In RS-3, W is the average *nominal* wage. With the exogenization of consumption and imports we have completely tied down GDP from the expenditure side. As will be explained shortly, with capital (K) pre-determined and the terms of trade (ToT) given, tying down GDP (Y) is enough to determine the real wage rate. Thus we are not free to specify the real wage rate via (1). Instead, in RS-3 we implement (1) with W being the nominal wage: consumer prices adjust so that the real wage is compatible with the already determined values of K, ToT and Y.

Although all the expenditure aggregates and GDP are fixed on their full recession growth rates we have still failed to produce a satisfactory recession simulation. The problem now is the result for the real wage rate. In row 24 of panel 3 real wages rise by 4.76 and 14.69 per cent above the baseline.

4. Diagnosing the problem

Three useful back-of-the-envelope equations for working out what is going wrong with the simulations discussed in the previous section are:

$$RW = MPL\left(\frac{K}{L}\right) \tag{6}$$

$$Y = F(K, L) \tag{7}$$

$$Y = C + I + G + X - M \tag{8}$$

where

RW is the real wage rate;

MPL is the marginal product of labour which is a function of the ratio of capital (K) to labour (L);

Y is output or GDP;

F is the production function assumed to be homogeneous of degree one; and

C, I, G, X and M are the expenditure components of real GDP.

Given this framework and standard USAGE assumptions, can we understand RS-1? What results should we expect for the effects of a cut in investment?

In the short run, we can think of RW as fixed (sticky real wage adjustment) and K as fixed (full capital utilization). Equation (6) then indicates that we should expect little short-run change in L in response to a downturn in I. Equation (7) now implies that we should expect little change in Y. Under standard USAGE assumptions, C is closely linked to Y and G is exogenous and unchanged. Thus from (8) we see that the main macro effect of a decrease in I is likely to be an improvement in the trade balance, an increase in X-M. This is borne out in the RS-1 results in Table 2, with particularly strong but unrealistic growth in exports.

This story is a little too simple. The results in panel 1 of Table 2 show short-run decreases in both Y and L (rows 15 and 16). To understand these results, we need to recognize that in RS-1 the sticky wage assumption [equation (1)] applies to the real wage defined as the nominal wage deflated by the price index for consumption whereas the real wage in equation (6) refers to the nominal wage deflated by the price index for GDP. We replace (6) with

$$\frac{W}{P_c} = \frac{P_g}{P_c} * \mathrm{MPL}\left(\frac{K}{L}\right) \qquad (9)$$

With an increase in exports, the U.S. suffers a reduction in its terms of trade.[4] This reduces P_g/P_c.[5] We can think of the LHS of (9) as being fixed in the short run. Thus, MPL rises. With K fixed, L must fall. Then from (7) we see that Y must also fall. So this is how, under standard USAGE assumptions, a reduction in I causes decreases in Y and L. But we still need to worry about the unrealistic increases in X.

Where do these increases in X come from? Assume that the nominal exchange rate is fixed. This is not an essential assumption but it simplifies the exposition because it means that movements in domestic prices directly change the international competitiveness of U.S. industries, that is they change the real exchange rate.[6] With a cut in investment, demand for inputs to construction and other investment-related industries is reduced. To a large extent, these industries produce non-traded goods. Thus a cut in domestic demand for their commodities

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4 We assume that foreign demand curves for U.S. exports slope down but that foreign supply curves for U.S. imports are flat.

5 P_g includes the prices of exports but not imports whereas P_c includes the prices of imports but not exports. Thus, decreases in the prices of exports relative to those of imports (terms of trade deterioration) tend to lower P_g/P_c.

6 We define the real exchange rate as $P_{US} * \phi / P_F$ where P_{US} and P_F are the price levels in the U.S. and foreign countries and ϕ is the nominal exchange rate, $F per $US. In a single country model such as USAGE, P_F is measured as an index of the foreign-currency prices of imports. The obvious alternative assumption to fixing ϕ is to fix P_{US}. In this case the movements in the real exchange rate that we discuss here are achieved via movements in ϕ with little difference in the implications for the real economy.

translates into a reduction in their outputs. With reduced output but fixed capital, industries producing non-traded goods must experience a reduction in their rental/wage ratio. With wage rates moving with the CPI, prices of non-traded investment-related goods fall relative to the CPI. The CPI is a combination of the prices of imported goods (which don't move) and the prices of domestic goods (some of which have fallen relative to the CPI). Thus, the CPI falls relative to the price of imported goods. This drags the wage down relative to the price of imported goods, generating an overall reduction in the domestic price level relative to the foreign price level. As illustrated in Figure 1, this causes an outward movement in the export supply curve taking us from the baseline solution at A to the solution for RS-1 at B. The problem is that the solution at B involves implausible export growth together with implausible real devaluation and decline in the terms of trade.

In RS-2, where we impose realistic export movements by allowing inward shifts in export-demand curves, the results for the real exchange rate and the terms of trade are even more implausible. The reduction in demand for exports initially imposes a squeeze on capital rentals in export-oriented industries, leading to further reductions in wages relative to the foreign price level, further real devaluation and further outward movement in export supply curves. This is illustrated in Figure 1: as we go from RS-1 to RS-2, the USAGE solution moves from B to C.

For understanding RS-3, we return to (7) to (9). In this simulation, reductions in Y are imposed via the exogenous settings of the components on the right hand side of (8). With K fixed and Y reduced, (7) implies a reduction in L. With the terms of trade fixed (implying little movement in P_g/P_c) equation (9) now leads to the unrealistic result that real wage rates must increase.[7]

Our conclusion from RS-1 to RS-3 is that for simulating the effects of a severe recession we must drop at least one of the standard CGE assumptions. Under these assumptions, equations (7) to (9) suggest that declines in Y and L require either (a) reductions in the terms of trade or (b) increases in real wages. Factor (a) operated in RS-1 and RS-2 and factor (b) operated in RS-3. The problem is that neither factor is operating in the current U.S. recession.

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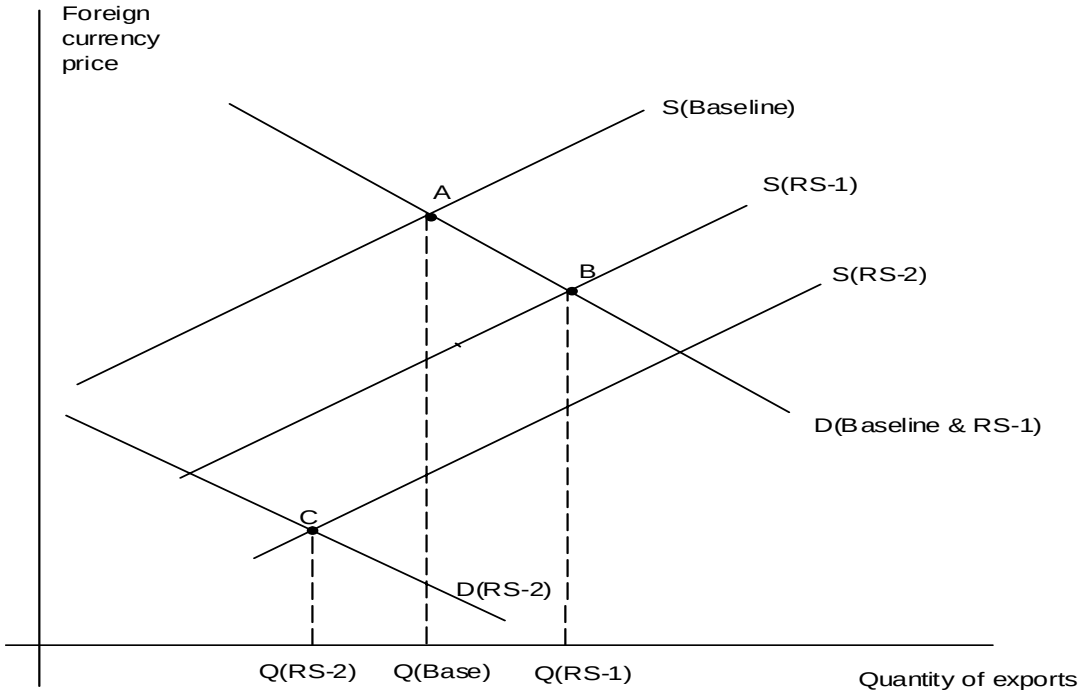
[7] We have been asked what is the numeraire in RS-3. In RS-1 and RS-2 it was the price of a bundle of import goods. In RS-3 we continue with a fixed exchange rate but we allow foreign-currency import prices to adjust to neutralize the terms of trade. In this circumstance there is a "numeraire equation" rather than a numeraire. The sticky nominal wage equation relates a price (money wage) to a real variable (employment) and to a predetermined price (lagged money wage). This is sufficient to allow the model to determine the price level in the current period.

Figure 1. Demand and supply curves for exports



5. Dropping the assumption of full capacity utilization

What assumption should we drop? The most attractive candidate is full-capacity utilization (pre-determined K).[8] Recessions are characterized by reductions in capacity utilization including factory closures. As indicated by Chart 1 in FRS (2009), there have been sharp reductions in capacity utilization in each of the seven U.S. recessions since 1970, including the current recession. Even when capital can be substituted for other factors, leaving capital stock idle is a rational response to recessionary conditions because there are fixed costs of keeping plants open.[9]

In section 4 we saw that the assumption of full capacity utilization implies unrealistic reductions in rental/wage ratios and the real exchange rate when demand falls. This suggests that in allowing for excess capacity, we should introduce sticky adjustment in rental rates. Rather than viewing rental rates as market clearing prices for the use of existing capital stocks, we

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[8] Another possibility, described by Robinson (2006), is to drop the assumption that capital and labour are paid according to their marginal products while retaining the assumptions of full-capacity utilization and sticky real wages. These assumptions imply that workers in a recession are paid less than the value of their marginal product. Labour hoarding ideas suggest that the opposite might be true.

[9] We do not explicitly include fixed costs in our CGE model, although this can be done, see for example Harris (1984) or Abayasiri-Silva and Horridge (1998). Explicit inclusion would overly complicate our model. Here, we do not explain excess capacity. Rather, we accept it as a real world phenomenon and model its consequences.

should view them as sluggishly adjusting mark-ups on variable costs (wage plus materials) which fall in response to excess capacity.[10] To implement these ideas, we introduced a distinction in USAGE between capital in use in industry j in year t [KU(j,t)] and capital in existence in industry j in year t [KE(j,t)]. In a reformulated recession simulation, RS-4, we limit the fall in rentals in the recession years, 2008 and 2009, and allow capital in use in each industry to fall below capital in existence. We keep the sticky rental adjustment mechanism for industry j in place in the years beyond the recession until the industry regains full or normal capacity utilization.

Figure 2 is a demand and supply representation of our sticky-rental/excess-capacity specification. In mathematical terms this specification is incorporated in the perturbation run[11] of RS-4 via the following equations and complementarity[12] relationships:

$$\left\{\frac{Q(j,t)}{Q_b(j,t)}-1\right\} = \left\{\frac{Q(j,t-1)}{Q_b(j,t-1)}-1\right\} + \alpha_2\left\{\frac{KU(j,t)}{KE(j,t)}-1\right\}+S(j,t) \text{ for all t ,} \qquad (10)$$

$$Q(j,t) = n_j\left(KU(j,t), ...\right) \quad \text{for all t} \qquad (11)$$

$$S(j,t) = 0 \quad \text{for} \quad t < t_c(j) \qquad (12)$$

$$S(j,t) \geq 0 \quad \text{for} \quad t = t_c(j) \qquad (13)$$

$$KU(j,t) = KE(j,t) \quad \text{for} \quad t \geq t_c(j) \qquad (14)$$

$$KU(j,t) \leq KE(j,t) \quad \text{for all t} \qquad (15)$$

In these relationships, Q(j,t) and Q_b(j,t) are the rental rates for industry j in year t in perturbation and baseline runs, and S(j,t) is a slack variable. α_2 is a positive parameter and t_c(j) is the year in

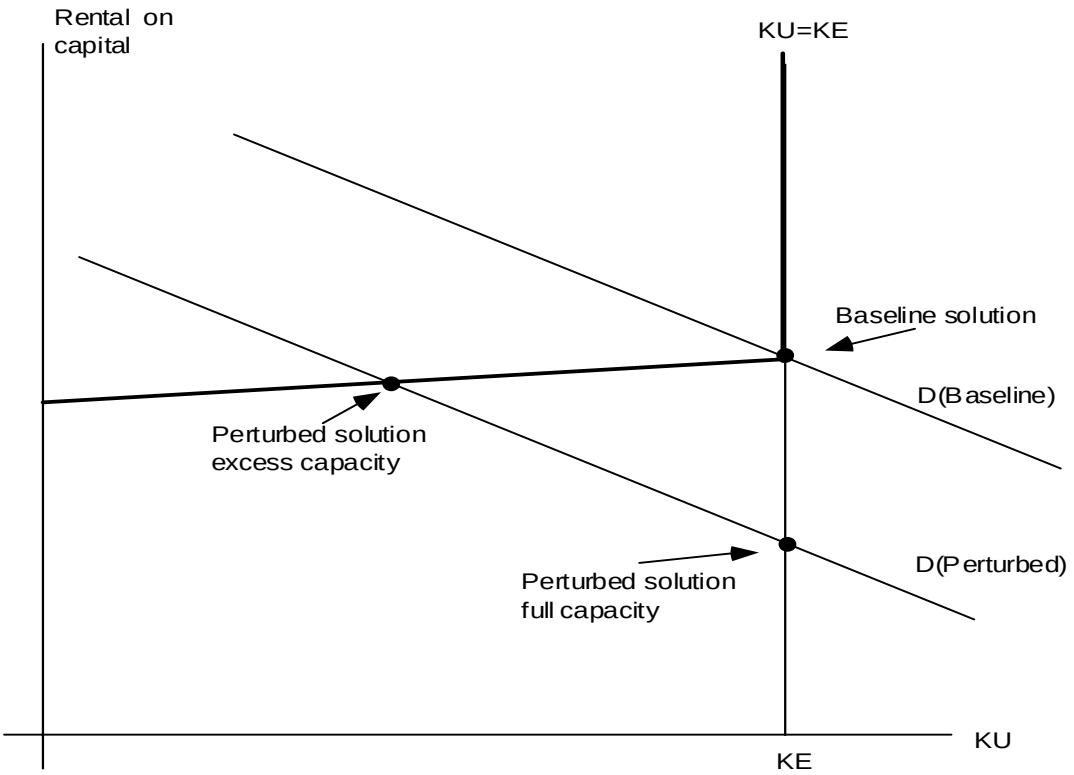
---

[10] There is a large literature on mark-up pricing starting with Hall and Hitch (1939) and Kalecki (1939). The literature is well summarized by Coutts (1987) and Eatwell (1987). Nevertheless, the implications of mark-up pricing do not seem to have been widely recognized by CGE modellers. An exception is Lance Taylor who has advocated mark-up pricing rather than marginal-cost pricing in CGE models for many years, see for example Taylor (1990). See also Dixon *et al*. (1979, pp. 36-40) in which the ORANI model was applied in fixed mark-up mode in an analysis of Australian recession-mitigating options in the late 1970s.

[11] In the baseline we continue to adopt the full utilization assumption.

[12] In the computations reported in sections 6 and 7, we used GEMPACK software with a complementarity facility (see Harrison *et al.*, 2004).

Figure 2. Demand and supply curves for capital: effects of a reduction in demand



which industry j regains full capacity utilization. Beyond $t_c(j)$, we assume that full capacity is maintained. Equation (10) is the sticky rental adjustment specification and equation (11) is the capital demand equation derived from the condition that the rental on capital is the value of the marginal product of capital in use.[13]

What do these relationships mean and how do they work? Let's assume that S(j,t) in (10) is on zero for all j. This imposes sticky adjustment of rental rates in year t. To see how the model now solves in broad macroeconomic terms, we continue to assume that the nominal exchange rate and the terms of trade are fixed and that, as in RS-3, the sticky wage assumption is implemented in nominal terms. We also assume that Y is given in (8) by exogenous determination of aggregate demand. With Y given we can restrict attention to combinations of capital in use (KU) and employment (L) that are compatible with the aggregate production function (7). With these combinations, we can use the sticky wage and rental equations [(1) and

[13] It has the same form as (5).

(10)] to trace out a downward sloping curve between KU/L and W/Q, and we can use the marginal productivity conditions [(9) and (11)] to trace out an upward sloping curve between KU/L and W/Q. The intersection of these two curves determines the factor input and factor price ratios. Knowing KU/L and Y is sufficient to tie down KU and L. The absolute factor prices (W and Q) can be determined from equations (1) and (10), thereby determining the domestic price level. In this process, higher values for Y give higher values for the domestic price level [via (1) and (10)] and therefore higher values for the real exchange rate. Thus we can trace out an upward sloping relationship between Y and the real exchange rate. Once Y becomes endogenous, we can we can think of it as being determined by the intersection of this upward-sloping relationship with a downward sloping relationship reflecting the negative effect on Y (via the trade balance) of increases in the real exchange rate.

But is condition (15) satisfied? In the simulations of the U.S. recession discussed in sections 6 and 7, S(j,t) is zero for all j in the perturbation runs in both 2008 and 2009 and every industry has excess capacity [KU(j,t) <KE(j,t)]. However, when we get to 2010, (15) would be violated for some industries if S(j,t) were set at zero. For these industries, output (and demand for capital) has recovered sufficiently by 2010 so that with S(j,t) at zero, the implied value for KU(j,t) is greater than the value for KE(j,t) determined at the end of 2009. For these industries, KU(j,t) is lowered to KE(j,t) and S(j,t) is determined endogenously. Lowering KU(j,t) tends to increase Q(j,t) so that from (10), S(j,t) becomes positive, consistent with (13). In this way we generate a valid solution in which some industries are operating at full capacity while other industries have excess capacity. Once an industry has regained full capacity we keep it on full capacity via (14) and we effectively drop (10) from the model by allowing S(j,t) to be determined endogenously with no sign constraint.

As well as allowing for excess capacity, we made two adjustments to the USAGE investment specification for each industry. First, we introduced the idea that expected rates of return on investment are likely to be lowered by the emergence of excess capacity. Second, we allowed demands for additional capacity in year t to be partially satisfied by re-commissioning excess capacity from year t-1. Mathematically, we specified investment via:

$$KE(j,t+1) = KE(j,t)*\left[1-D(j)\right] + I(j,t) \quad \text{for all t} \tag{16}$$

$$\frac{I(j,t)}{KE(j,t)} - D(j) = f_j\left[EROR(j,t), H(j,t)\right] - \alpha_3 * \left[1 - \frac{KU(j,t-1)}{KE(j,t-1)}\right] \quad \text{for all t} \tag{17}$$

$$EROR(j,t) = \left[\frac{KU(j,t)}{KE(j,t)}\right] * g_j\left[Q(j,t), ...\right] - \left[1 - \frac{KU(j,t)}{KE(j,t)}\right] * D(j) \quad \text{for all t} \tag{18}$$

Equation (16) specifies that capital in existence for industry j at the beginning of year t+1 is the depreciated capital from the beginning of year t plus investment during year t. The first term on the RHS of (17) is the standard USAGE function relating capital growth through year t to the expected rate of return on investment made in year t [see (3)]. The second term damps investment by allowing some of industry j's capital requirements to be satisfied by re-commissioning capital that was unused in year t-1. To see how this works suppose that α_3 = 0.33. If expected rates of return justify capital growth through year t of 5 per cent (f_j = 0.05) but excess capacity was 10 per cent in year t-1, then capital growth [the left hand side of (17)] is reduced to 1.7 per cent (= 5 – 0.33*10). Finally, in equation (18) we assume that the expected rate of return is a weighted average of the rate of return (g_j) for capital in use computed via its rental rate [see (4)] and of the negative of the depreciation rate. The weights are the share of capital in existence that is in use and the share not in use. We assume that capital not in use has a rate of return of the negative of the depreciation rate (it earns no rental and deteriorates at the depreciation rate).

6. The recession with excess capacity

Panel 4 in Table 2 reports 2008-9 results for a full-recession simulation, RS-4, computed in the USAGE model enhanced by equations (10) to (18).

With the enhanced model we can impose the full recession scenario from Table 1 without requiring unrealistic movements in any of the variables that were troublesome in RS-1 to RS-3. In RS-4 the horizontal shifts in export demand curves (-0.87 and -20.57 per cent, row 12, panel 4) are consistent with what could be expected on the basis of the contraction in the world economy; the real exchange rate and real wage rate barely move (rows 21 and 24); and the assumption of no movement in the terms of trade is accommodated with little movement in the foreign-currency prices of imports (row 20).

How does the enhanced model work? Why can we now accommodate sharp reductions in Y and L without requiring either (a) reductions in the terms of trade or (b) increases in real wages? Under standard USAGE assumptions, stickiness in real wage rates and fixity of capital severely limit the scope for short-run movements in employment, especially if there is little movement in the terms of trade, see equation (9) and the related discussion. In the enhanced model, capital in use can fall, dragging employment with it. Thus, employment can move in the short run without requiring movements in real wage rates or the terms of trade. Consistent with Keynesian logic we can think of Y in equation (8) as being set by demand (C+I+G+X-M) and K and L adjusting together to accommodate the demand-determined movement in Y. The movement in the K/L ratio is limited by the assumption of sticky factor prices which implies rather little movement in relative factor prices.

7. Recession and recovery without the Obama package and with the package

This section describes two simulations. In the first we extend the RS-4 simulation described in section 6 to cover the period 2008 to 2015. In the second, RS-O, we superimpose the Obama stimulus package on the extended RS-4 simulation. In both simulations the baseline growth rates in each year are those in the left hand panel of Table 1.

As explained earlier, in the RS-4 perturbation run for 2008-9, shift variables affecting consumption, investment, exports, imports and the terms of trade were treated endogenously to allow these variables to be set exogenously on recession paths. In extending RS-4 to cover 2010 to 2015 we exogenize the shift variables and endogenize consumption, investment, exports, imports and the terms of trade. We assume in the extended perturbation run that consumer and investor confidence, the positions of export demand curves, import/domestic preferences and import supply conditions gradually return to their baseline paths. In implementing this assumption we keep the shift variables in 2010 at their 2009 values. We think of 2010 as a pause year. Recovery commences in 2011 and the shift variables reach their baseline values in 2015.

In RS-O we represent the Obama package as additions to public consumption and private benefits (additional to levels in RS-4). The additions to public consumption are 0.85 per cent in 2009 and 2.7 per cent in 2010, while the additional benefits to households are worth about 1.6

per cent and 3.2 per cent of household consumption in 2009 and 2010.[14] With public and private consumption being about 17 and 71 per cent of GDP, the package is a direct boost to GDP of 1.3 per cent in 2009 (= 0.85*0.17 + 1.6*0.71) and 2.7 per cent in 2010 (= 2.7*0.17 + 3.2*0.71). Beyond 2010 we assume that these additions to public consumption and private benefits are unwound so that by 2015 public consumption and benefit rates have returned to their baseline paths.

In simulating the Obama package (which starts in 2009) it would be inappropriate to set growth in consumption, investment, etc exogenously in 2009: we want to know how these variables are affected by the package. Instead we set the shift variables exogenously on the values they had in the perturbation run of RS-4. This is true not only for 2009 but for all subsequent years. In the absence of the package shocks, RS-O would have reproduced the results from the extended RS-4. The package shocks move the results for RS-O away from those in RS-4. Comparison of results in the two simulations reveals the effects of the package.

7.1. Recession without the Obama package

Chart 1 presents results from the extended RS-4 perturbation run in year-on-year growth terms. For 2008 and 2009 it shows the exogenously imposed growth rates from the right hand panel of Table 1. For example, it shows growth rates of -6.60 and -25.00 per cent for investment in these years. Without the Obama package, Chart 1 indicates that GDP will continue to decline in 2010, by 2.4 per cent. The main source of the decline is investment. Despite our assumption that investor confidence stops falling in 2010, investment drops by a further 25 per cent. This is because excess capacity from 2009 is being worked off in 2010. A bright spot in 2010 is export growth which moves from -10 per cent in 2009 to 9 per cent in 2010. The upsurge in exports reflects two factors: (a) export demand curves in 2010 stop moving to the left; and (b) U.S. real wage rates and profit margins fall relative to those in the rest of the world, generating real devaluation. Factor (a) allows strong baseline growth (6.03 per cent) in exports to re-emerge and factor (b) provides additional stimulation of exports. Underlying factor (b) is the implicit assumption in our forecasts that while the world economy has stopped declining in 2010 (foreign demand curves for U.S. exports are no longer moving to the left), the U.S. economy continues to

[14] We base these estimates on the letter of March 2, 2009 from D.W. Elmendorf, Director, Congressional Budget Office, to Honorable C.E. Grassley, Committee of Finance, United States Senate, available at http://www.cbo.gov/ftpdocs/100xx/doc10008/03-02-Macro_Effects_of_ARRA.pdf .

decline (U.S. GDP growth is still negative). Consumption and imports in 2010 decline broadly in line with GDP.

Beyond 2010, Chart 1 shows strong and increasing growth in GDP up to 2013. This reflects rapid growth in investment as confidence returns and excess capacity disappears. Strong growth in investment causes real appreciation, damping export growth and stimulating import growth. In 2014-15, GDP and its components resume a normal growth pattern as the echo of the recession dies away.

Charts 2 and 3 present results from the perturbation run of RS-4 as deviations from the no-recession baseline. The deviation results bring out the seriousness of the recession. For example, Chart 3 shows that the recession (without the Obama package) reduces employment in 2008, 2009 and 2010 by 3, 10 and 15 per cent relative to where it would have been in the absence of the recession. These deviations reflect baseline employment growth in each year of 1.1 per cent and recession growth rates in the three years of -1.5, -6.9 and -4.7 per cent.[15]

Although the economy recovers in year-on-year growth terms by about 2011, the charts imply that the recession will cause longer-lasting damage. In 2015, Chart 2 shows private consumption is still 1.6 per cent below its baseline level. If we integrate the consumption deviations from 2008 to 2015 we see that the no-package recession over this period costs the economy 59 per cent of a year's consumption. A partial offset to these losses is that the recession improves the trade balance for most of the simulation period. By 2015 the ratio of net foreign liabilities to GDP in RS-4 is 37 per cent, down from 46 per cent in the baseline forecast. With private consumption being about 70 per cent of GDP this reduction in net foreign liabilities is equivalent to a consumption gain of about 13 per cent [= (46-37)/0.7]. Thus in net terms the recession, without a stimulus package, costs the U.S. about 46 per cent of a year's consumption (= 59-13).

Chart 3 shows the relationship between the deviation paths for aggregate capital in use (KU) and aggregate capital in existence (KE). The recession weakens investment for the period 2008 to 2013 (Chart 2). Consequently, KE falls relative to the baseline throughout this period.

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[15] Employment in USAGE is measured in hours of labour input. The decline in the number of employed people is likely to be less than that in labour input, reflecting cuts in hours per worker.

Chart 1. Real expenditure aggregates: recession with no package (RS-4), year-on-year growth rates

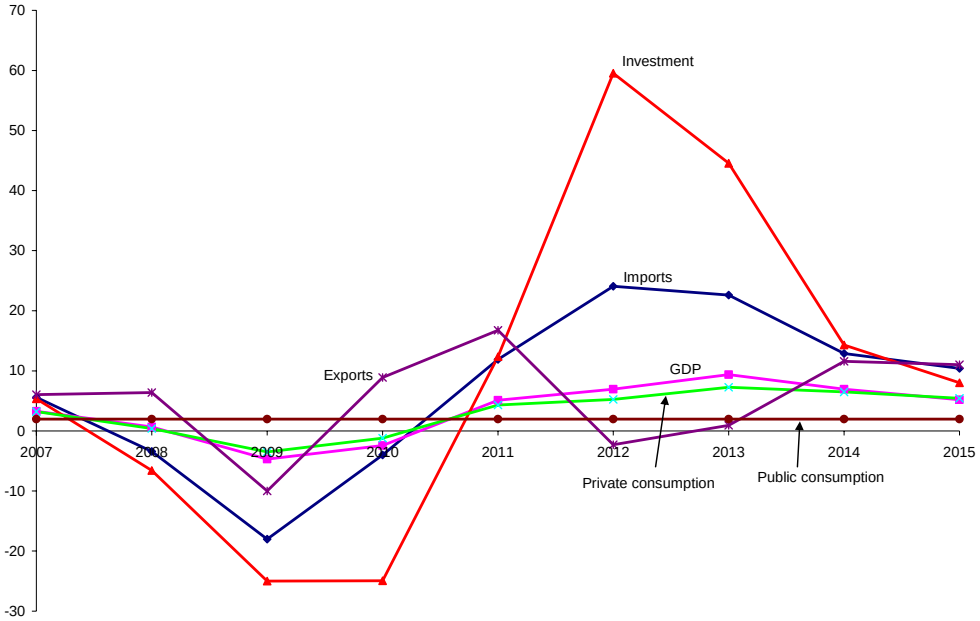


Chart 2. Real expenditure aggregates: recession with no package (RS-4), percentage deviations from baseline

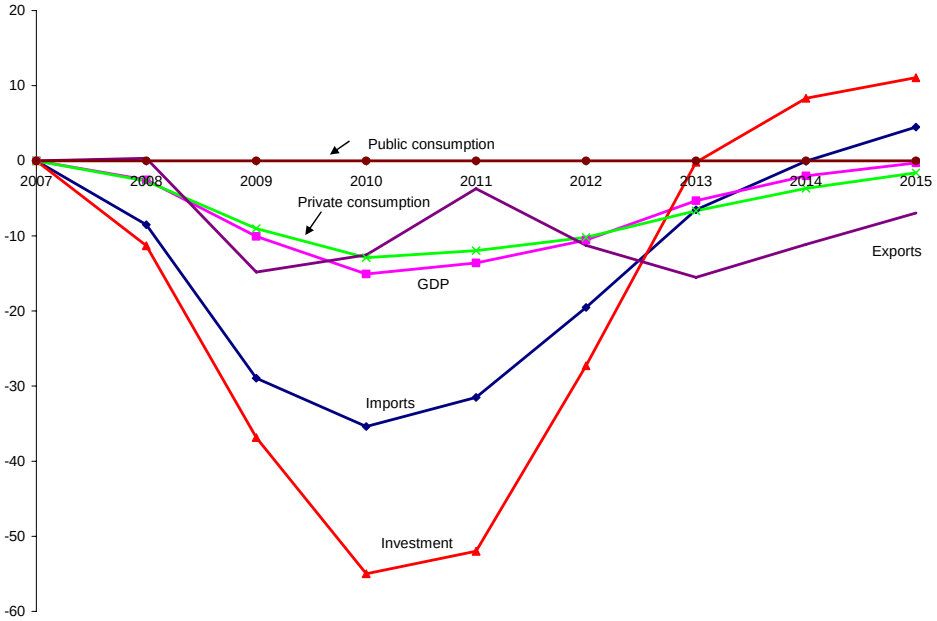
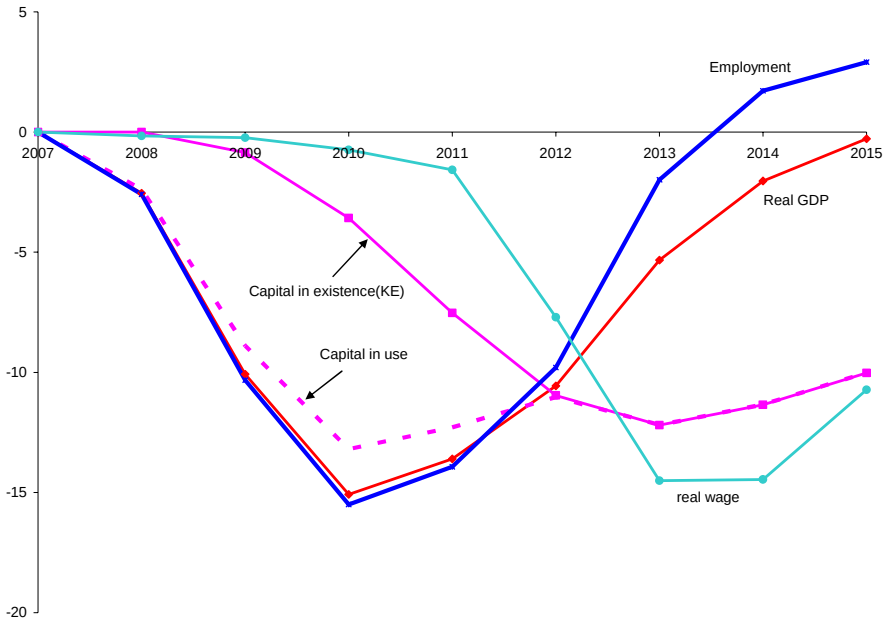


Chart 3. GDP, primary factors& real wage rate : recession with no package (RS-4), percentage deviations from baseline



KU falls dramatically relative to the baseline in the recession years of 2008 to 2010. Beyond 2010, KU recovers with the recovery of the economy. With KU increasing and KE falling excess capacity is eliminated by 2012.

Another interesting aspect of Chart 3 is the behaviour of the average real wage rate. Up to 2011, there is little movement in the real wage rate relative to the baseline. While there is excess capacity and employment is below its baseline path, nominal capital rentals and nominal wage rates both adjust sluggishly downwards, see equations (10) and (1). This causes sluggish downward adjustment in the price level, leaving little scope for movements in real wage rates. Once full capacity utilization is regained, real wage rates fall sharply. Nominal wages continue to adjust down relative to the baseline reflecting continuing low employment while nominal rentals rise sharply reflecting capital scarcity and recovering demand. By 2014, real wages are sufficiently low to push employment above its baseline level. With tightening of the labor market, real wages then begin to recover towards their baseline level.

7.2. Recession with the Obama package

To what extent does the Obama package mitigate the adverse effects of the recession? Charts 4 to 8 compare results from RS-4 (without the package) with those from RS-O (with the package). As already mentioned, the package provides direct stimulations to GDP in 2009 and 2010 of about 1.3 and 2.7 per cent. Chart 4 shows that these direct stimulations generate increases in GDP in the two years of 2.3 per cent (= 10.1-7.8) and 6.2 per cent (= 15.1-8.9). Thus, our simulations give multipliers of 1.8 (= 2.3/1.3) and 2.3 (= 6.2/2.7).

From USAGE simulations conducted under the assumption of full capacity utilization, we are used to thinking of multipliers that are close to zero (certainly less than one). If we stimulate public or private consumption then with full capacity utilization we get a largely offsetting deterioration in the trade balance brought about by real appreciation triggered by sharp increases in rental rates on capital in industries producing non-traded goods.[16] Now, with the excess-capacity specification, an increase in demand produces relatively little effect on the real exchange rate and therefore only small reductions in exports and small increases in imports (Chart 5). Thus, the trade balance provides only a small offset to the direct effect on GDP of demand stimulation. With the direct effect not being significantly offset, USAGE generates substantial indirect effects (multiplier effects). Direct increases in GDP expand employment of both labour and capital (Charts 6 and 7). This stimulates consumption and investment (Chart 8), thereby providing increases in demand and GDP beyond the direct effects.

The comparison of RS-4 and RS-O in Charts 4 to 8 implies that the package strongly reduces the costs of the recession. Looking at private consumption, for example, we see that the package limits accumulated losses over the period 2008 to 2015 to 22 per cent of a year's consumption, down from 59 per cent without the package. However, the package worsens the trade balance (Chart 5) thereby increasing net foreign liabilities from 37 per cent of GDP in 2015 to 42 per cent. We conclude that the package generates a net benefit worth about 30 per cent of a year's consumption [= (59-22) – (42-37)/0.7].

[16] Similar mechanisms lead to low multipliers on increases in public expenditure and associated trade-balance deterioration in DSGE models such as QUEST III (see Ratto *et al.* 2009, Figure 1a).

Chart 4. Real GDP: recession with & without Obama package (RS-O & RS-4), percentage deviations from baseline

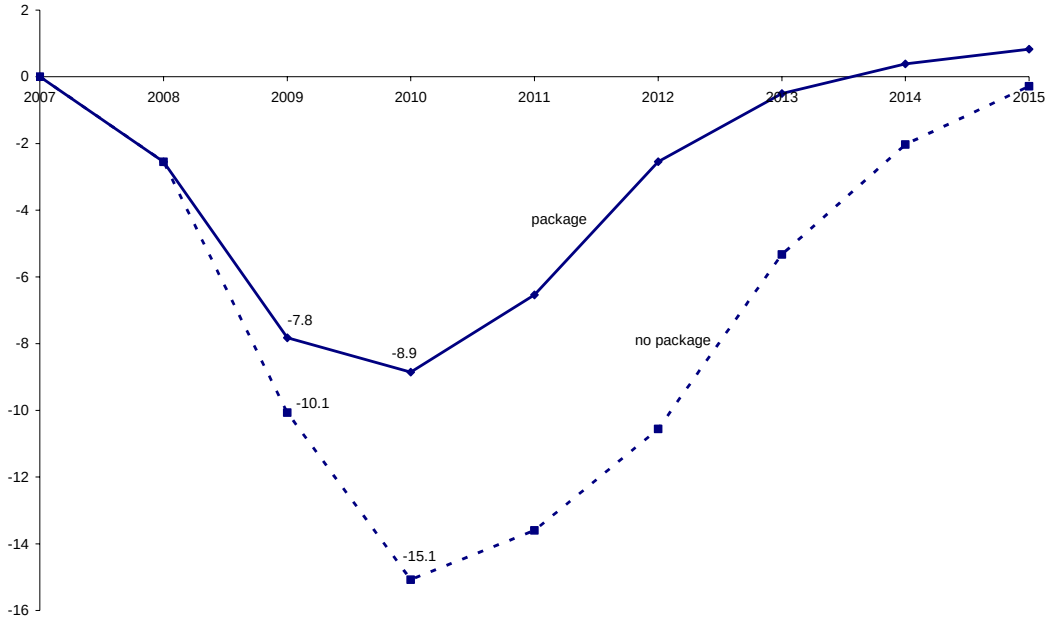


Chart 5. Trade volumes: recession with & without Obama package (RS-O & RS-4), percentage deviations from baseline

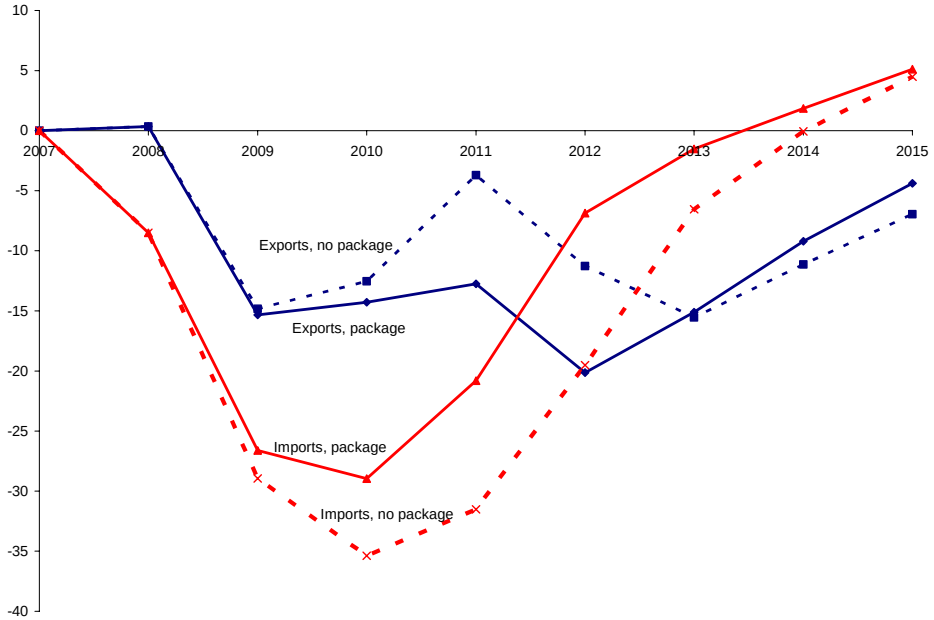


Chart 6. Employment & wages: recession with & without Obama package (RS-O & RS-4), percentage deviations from baseline

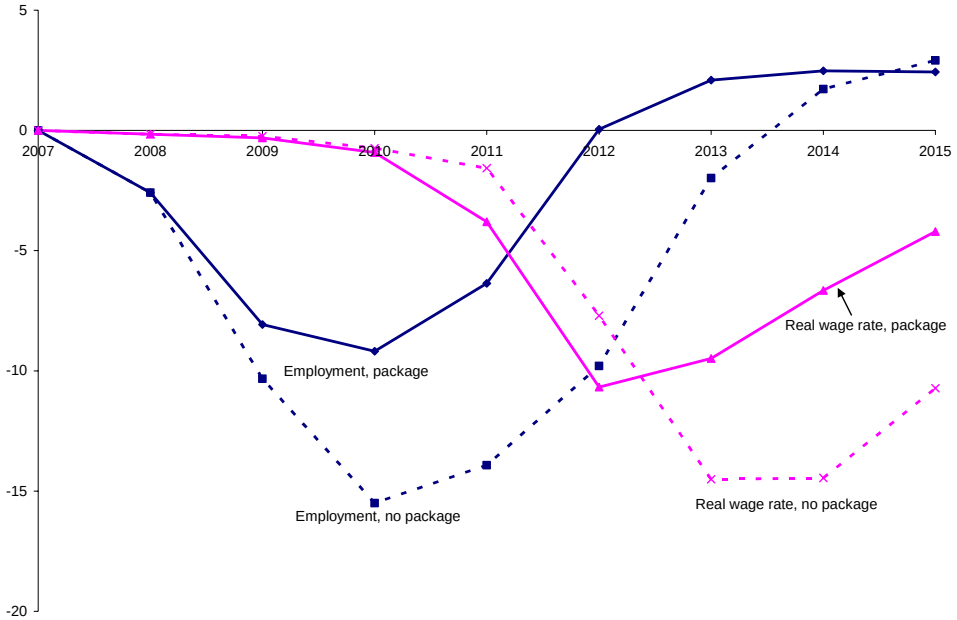
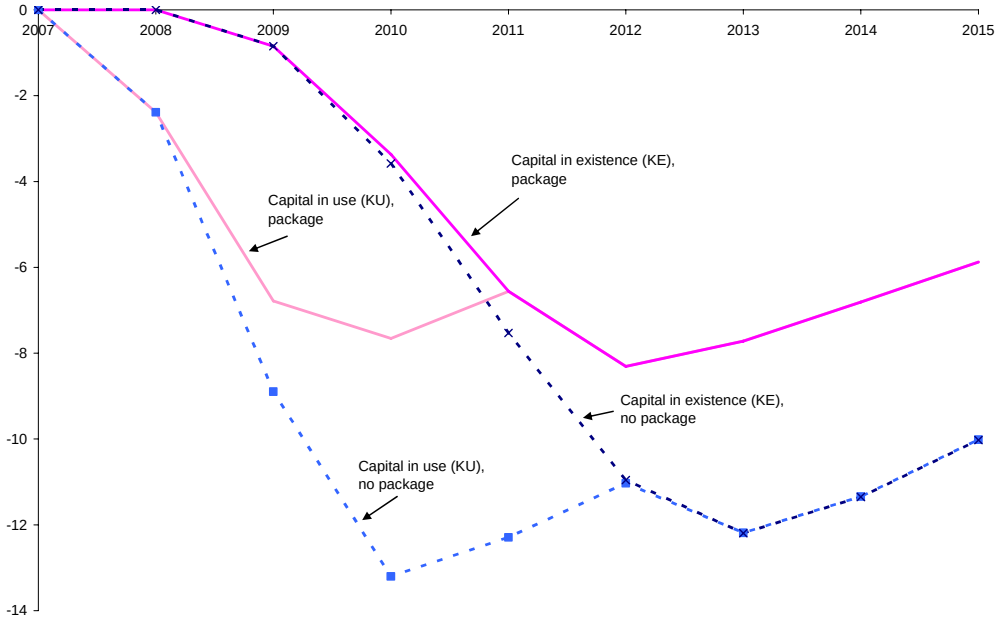
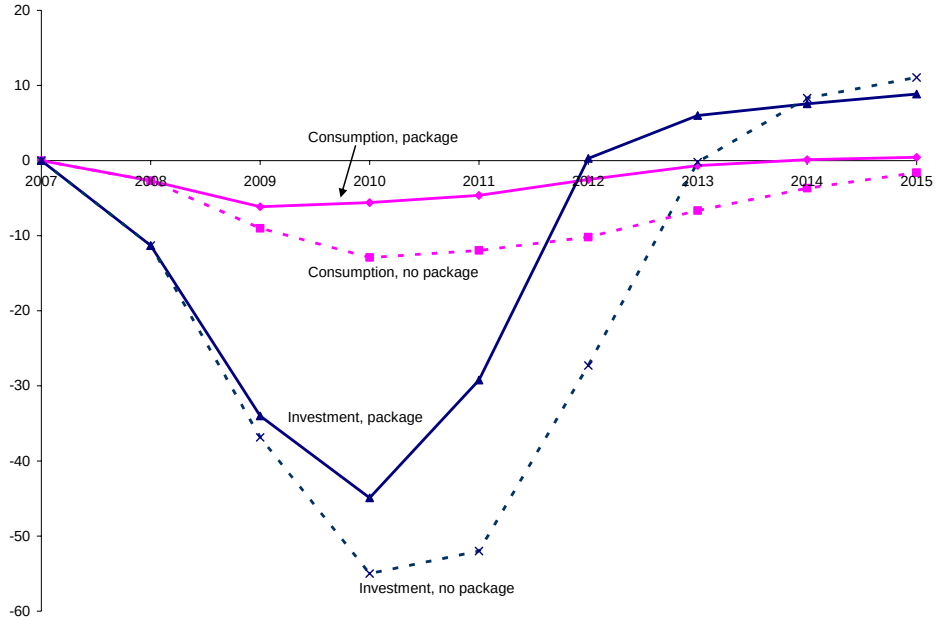


Chart 7. Capital: recession with & without Obama package (RS-O & RS-4), percentage deviations from baseline



***C**hart 8. Consumption & investment: recession with & without Obama package (RS-O & RS-4), percentage deviations from baseline*

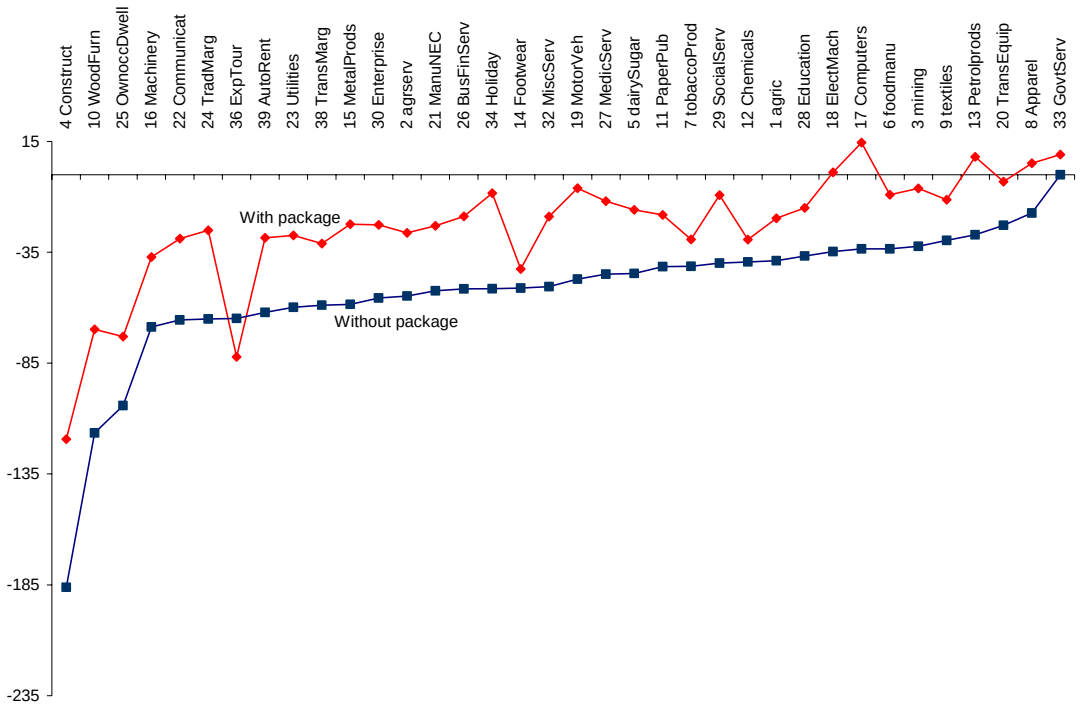


7.3 Industry results

Chart 9 shows the effects of the recession on industry outputs with and without the Obama package (RS-4 and RS-O). The points in the chart are accumulated output deviations over the eight years from 2008 to 2015. Thus for example, the chart implies that without the package the recession reduces Construction output by 186 per cent of a year's output. With the package , the recession reduces Construction output by 119 per cent of a year's output.

Three points are immediately apparent. First, the recession has widely varying effects across industries. Without the Obama package these range from -186 per cent of a year's output (Construction) to 0 per cent (Government services), and with the package they range from (-119 per cent (Construction) to 14 per cent (Computers). Second, the package has positive effects on industry outputs with only one exception. Comparison of the two lines in Chart 9 shows that these effects are uneven: the package raises Construction output across the period by 67 per cent of a year's output whereas for Footwear and Government services the beneficial effects are only 9 per cent of a year's output. For Export tourism the package has a negative effect: a reduction

Chart 9. Effect of recession on industry outputs 2008-15, percentage of one year's output



of 17 per cent effect: a reduction of 17 per cent of a year's output. Third, even with the package, the recession has strongly negative effects for most industries. However, there are five industries (Electrical machinery, Computers, Petrol products, Apparel and Government services) where the package lifts recessionary accumulated output for 2008 to 2015 above the no-recession baseline.

Table 3 shows recession-related deviations accumulated for the years 2008 to 2015 for the expenditure components of GDP. These results help explain differences in the effects of the recession across industries and differences in the stimulation that they receive from the Obama package.

In the no-package simulation, industries are particularly adversely affected by links with investment for which the total recession-related reduction is 163.3 per cent of a year's expenditure [Table 3, column (1)]. Thus the Construction industry, which relies heavily on economy-wide investment expenditure, is the most recession-damaged industry (it appears at the

Table 3. Effect of recession on real expenditure aggregates 2008-15,

percentage of one year's level

	Without package (1)	With package (2)	Effect of package (3) = (2) - (1)
Private consumption	-58.7	-21.7	37.0
Investment	-163.3	-96.8	66.5
Public consumption	0.0	9.1	9.1
Exports	-75.6	-90.8	-15.2
Imports	-126.0	-86.3	39.6
GDP	-59.5	-27.6	31.9

extreme left in Chart 9). Wood Furniture is the second most recession-damaged industry. It owes its low ranking in Chart 9 not to its direct sales to investment but to its sales to the Construction industry. Another negative factor influencing the rankings in Chart 9 is dependence on export sales. The most export-oriented industry is Export tourism which provides services to visitors to the U.S. With a relatively sharp recession-related contraction in exports [75.6 per cent compared with GDP contraction of 59.5 per cent, column (1) Table 3], export tourism ranks quite low in Chart 9, seven places from the left. On the other hand, import-competing industries are somewhat insulated from the recession by the sharp contraction in imports (126.0 per cent of a year's expenditure). Thus industries such as Apparel, Petroleum products, Chemicals, Textiles and Mining suffer relatively little recession-related contraction (they appear at the right in Chart 9). Contraction of imports also explains the relatively benign effect of the recession on Computers and Motor vehicles despite their dependence on investment expenditure. Government services does not suffer recession-related output contraction in the no-package simulation because we assume that public consumption is unaffected. Ownership of dwellings suffers a relatively sharp reduction in output (it appears four places from the left in Chart 9). This industry produces shelter using the housing stock as its principal input. Thus, it is highly capital intensive. The sharp downturn in investment caused by the recession leaves the economy short of housing stock in the later years of the simulation period, directly explaining the reduction in the industry's output. More generally, in the later years of the simulation period, capital shortages increase the relative prices of capital-intensive commodities, causing a shift in demand against these commodities in favour of labour-intensive commodities.

In summary, this description of the industry results in Chart 9 for the no-package simulation suggests that there are six explaining factors: dependence on investment sales

(negative); dependence on sales to the construction industry (negative); dependence on sales to export (mildly negative); exposure to competition from imports (positive); dependence on sales to government (positive); and labour intensity (positive). One way of checking the validity of this description is by running a regression in which the industry results from the no-package simulation are on the left hand side and the factors that we think explain the results are on the right hand side. On doing this we obtained the regression equation:

$$Z_{without} = -52.285 - 23.978 * V_I + 19.977 * V_M - 0.234 * V_X + 10.502 * V_G - 12.005 * V_{const} + 8.422 * V_{lab} \qquad R^2 = 0.851 \qquad (19)$$

where

$Z_{without}$ is the vector of industry results shown for the no-package simulation in Chart 9;
V_I, V_X, V_G, V_{const} and V_{lab} are vectors reflecting: the share of sales by each industry going to investment, exports, government and the Construction industry as intermediate inputs;
V_M is a vector reflecting the share of imports in each industry's domestic market; and
V_{lab} is a vector reflecting the share of labour in each industry's returns to primary factors (labour plus capital).

We say "reflecting" because the vectors are transformed from original data on shares by deviating from means and dividing by standard deviations[17]. This means that all of the variables appearing on the right hand side of (19) have mean zero and variance one. Normalizing in this way does not affect the fit of a regression equation (R^2). However, it assists in the interpretation of the regression coefficients.

With the means of all of the right-hand variables on zero, the constant term on the right hand side of (19) measures the average loss of output across industries in the no-package simulation, 52.285 per cent of a year's output. With the standard deviations of all variables on 1, the regression coefficients indicate the relative importance of variability in each factor in causing differences across industry results.[18] As anticipated, reliance on investment sales is a strongly negative factor (-23.978), import competition is a strongly positive factor (+19.977), sales to

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[17] In the case of import shares, the variable that we transform is $S_{M\_mod} = S_M * (1-S_M)^{\wedge 1.5}$. In our perturbation simulations, the macro target for imports is met by including on the right hand side of demand equations for domestic products the term $-S_{M\_mod}$*twist where twist in endogenously determined at large negative values. Up to a value for S_M of 0.4, S_{M_mod} is an increasing function of S_M. Thus, import exposure is assumed to provide increasing insulation from the recession as S_M increases from 0 to 0.4. There are just two industries, Footwear and Apparel, with S_M >0.4. Our use of S_{M_mod} ensures that these two declining industries are not shown to have strongly revitalized prospects on account of the recession.

[18] The coefficients indicate relative importance in an unambiguous way only if the covariance terms $\hat{b}_j * \hat{b}_k * \mathrm{cov}(V_j, V_k)$ for any pair of right hand variables j and k are zero, where $\hat{b}_j$ and $\hat{b}_k$ are the regression coefficients. As can be seen from Table A1 in the Appendix, the covariance terms from equation (19) make relatively minor contributions to the explanation of the variance in the left hand variable. .

exports is a minor negative factor (-0.234), sales to government is a positive factor (+10.502), sales to Construction is a negative factor (-12.005) and labour intensity is a positive factor (+8.442). Overall, the six factors explain a high percentage (85.1) of the variability across industries in the no-package results.

Equation (20) is a regression description of the effect of the Obama package on industry outputs for the period 2008 to 2015:

$$Z_{difference} = 28.652 + 7.173 * V_I - 0.771 * V_M - 9.886 * V_X - 4.362 * V_G + 1.725 * V_{const} + 0.745 * V_{lab} \qquad R^2 = 0.878 \qquad (20)$$

The left hand variable for each industry is the difference between the with-package result (generated in RS-O) and the without-package result (RS-4), that is, it is the difference between the results shown in Chart 9. The right hand variables are the same as in (19).

The constant term in (20) indicates that the average benefit across industries from the package for the period 2008-15 is worth 28.652 per cent of a year's output. The coefficients on the variables indicate that the package is good for industries that sell to investment directly or indirectly via sales to Construction, but not good for export industries.[19] This could be anticipated on the basis of Table 3 which shows that the package strongly stimulates investment relative to GDP [66.5 per cent compared with 31.9 per cent, column (3)], while causing a contraction in exports (-15.2 per cent). Sales to government is a negative factor because the stimulatory effect of the package on public consumption (9.1 per cent) is considerably smaller than that on GDP (31.9 per cent). Import exposure is a minor negative factor because the package stimulates imports slightly relative to GDP (39.6 per cent compared with 31.9 per cent). Labour intensity is an insignificant factor in determining the industry effects of the package.

8. Concluding remarks

Full capacity utilization is a standard assumption in CGE modelling. Of course, CGE modellers realize that excess capacity is a real world feature of a recession. Under the assumption of full-capacity utilization and a market-clearing rental rate, standard CGE models show less than normal L/K ratios in simulations of depressed periods, and it is sometimes argued

[19] As can be seen in Table A1, the covariance terms generated from equation (20) are very small implying that the regression coefficients are good indicators of the contributions of the variability in the right hand variables to the variability in the left hand variable.

that this is sufficient to represent excess capacity.[20] The problem with this approach is that it involves sharp reductions in rental rates on capital in response to reductions in demand. This leads to real depreciation (a reduction in the price level in the U.S. relative to the price level in the rest of the world). Thus, when we simulate the effects of reductions in domestic demand (C, I, G) with full capacity utilization it is virtually impossible to generate short-run results without an export upturn. When this is unrealistic, as in the present U.S. situation, then we can impose inward movements in foreign demand curves. But this leads to large simulated declines in the terms of trade and further real depreciation: neither of which are descriptive of the present U.S. situation. When we introduce shifts in import prices to get rid of terms-of-trade and real-exchange-rate movements, then the model implies large and implausible increases in real wage rates. It appears that a realistic CGE picture of the present U.S. situation can be obtained only when we allow for excess capacity via sticky adjustment of capital rentals.[21]

In this paper, we have introduced such a specification and made corresponding modifications to the theory of investment. With these additions to the CGE model, we are able to simulate the effects on the U.S. economy of reductions in domestic and foreign demand in 2008-9 without unrealistic movements in the terms of trade, the real exchange rate or real wage rates.

Many scenarios are possible for the period beyond 2009. In this paper we have assumed a steady return by 2015 to baseline levels for variables representing investor and consumer confidence and world trading conditions. Under our assumptions, the Obama stimulus package plays a valuable role in mitigating the economic costs of the recession. Without the package the recession imposes a total cost on the U.S. economy up to 2015 of about 46 per cent of a year's consumption. With the package this cost is reduced to about 16 per cent of a year's consumption.

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[20] This argument is explicit in Dixon *et al.* (1982, p. 29).

[21] Excess capacity can be generated in a CGE model without the sticky-rental assumption by assuming zero substitutability between capital and other factors of production including labour. In this case, reductions in demand generate reductions in capital in use. However, this approach exacerbates the problem of unrealistic movements in rental rates and the real exchange rate.

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Appendix A1. Industry results: additional information on regression equations (19) and (20)

Table A1 shows decompositions based on equations (19) and (20) of the variance in the industry effects of the recession and of the Obama package. These decompositions are based on the identities

$$\mathrm{Var}(Z) = \sum_j \sum_k \hat{b}_j * \hat{b}_k * \mathrm{cov}(V_j, V_k) + \mathrm{Var}(\mathrm{error}) \qquad \textit{(A1)}$$

and

$$R^2 = \sum_j \sum_k \hat{b}_j * \hat{b}_k * \mathrm{cov}(V_j, V_k) / \mathrm{Var}(Z) \quad . \qquad \textit{(A2)}$$

The table indicates that most of the covariance terms for equation (19) are quite small and all of the covariance terms for equation (20) are small. This supports our interpretation of the coefficient values as indicators of the relative importance of the six factors in explaining variability across industries in the simulated effects of the recession and of the Obama package.

Charts A1and A2 show model results for the effects of the recession and of the Obama package together with fitted values from equations (19) and (20). These charts can be used to deepen our understanding of the industry results. For example, looking at Chart A1, we can ask why the model is more pessimistic about recession damage to the Transport margin industry than regression equation (19). What does the model know about the Transport margin industry that is not included in the regression? Similar questions apply to the Holiday industry and Chemicals. Questions with the opposite sign apply to Computers and Transport equipment. We think the answers to some of these questions involve detailed sales patterns. For example, Transport margins are used intensively in facilitating international trade which is particularly adversely affected by the recession: the link between Transport margins and trade is incorporated in the model but not the regression. For other questions, income elasticities may be relevant. For example, demand for Holidays is income elastic which means that this industry is particularly susceptible to recession-related reductions in income. Again, this is incorporated in the model but not in the regression. Proceeding in this way, we can develop theories about all of the industry results that are not well-explained by regression equation (19). These theories can be tested by including additional regression variables.

Table A1. Decompositions based on equations (19) and (20) of the variance in the industry effects of the recession and of the Obama package

	Without package, equation (19)	With – without package, equation (20)
$\hat{b}_I^2 * \text{var}(V_I) / \text{var}(Z)$	0.604	0.267
$\hat{b}_M^2 * \text{var}(V_M) / \text{var}(Z)$	0.419	0.003
$\hat{b}_X^2 * \text{var}(V_X) / \text{var}(Z)$	0.000	0.507
$\hat{b}_G^2 * \text{var}(V_G) / \text{var}(Z)$	0.116	0.099
$\hat{b}_{const}^2 * \text{var}(V_{const}) / \text{var}(Z)$	0.151	0.015
$\hat{b}_{lab}^2 * \text{var}(V_{lab}) / \text{var}(Z)$	0.075	0.003
$2 * \hat{b}_I * \hat{b}_M * \text{cov}(V_I, V_M) / \text{var}(Z)$	-0.259	-0.015
$2 * \hat{b}_I * \hat{b}_X * \text{cov}(V_I, V_X) / \text{var}(Z)$	0.000	0.001
$2 * \hat{b}_I * \hat{b}_G * \text{cov}(V_I, V_G) / \text{var}(Z)$	0.031	0.019
$2 * \hat{b}_I * \hat{b}_{const} * \text{cov}(V_I, V_{const}) / \text{var}(Z)$	0.079	0.017
$2 * \hat{b}_I * \hat{b}_{lab} * \text{cov}(V_I, V_{lab}) / \text{var}(Z)$	-0.125	0.016
$2 * \hat{b}_M * \hat{b}_X * \text{cov}(V_M, V_X) / \text{var}(Z)$	-0.001	0.008
$2 * \hat{b}_M * \hat{b}_G * \text{cov}(V_M, V_G) / \text{var}(Z)$	-0.096	-0.008
$2 * \hat{b}_M * \hat{b}_{const} * \text{cov}(V_M, V_{const}) / \text{var}(Z)$	-0.181	-0.005
$2 * \hat{b}_M * \hat{b}_{lab} * \text{cov}(V_M, V_{lb}) / \text{var}(Z)$	0.013	0.000
$2 * \hat{b}_X * \hat{b}_G * \text{cov}(V_X, V_G) / \text{var}(Z)$	0.001	-0.061
$2 * \hat{b}_X * \hat{b}_{const} * \text{cov}(V_X, V_{const}) / \text{var}(Z)$	0.000	0.009
$2 * \hat{b}_X * \hat{b}_{lab} * \text{cov}(V_X, V_{lab}) / \text{var}(Z)$	0.000	-0.005
$2 * \hat{b}_G * \hat{b}_{const} * \text{cov}(V_G, V_{const}) / \text{var}(Z)$	0.031	0.009
$2 * \hat{b}_G * \hat{b}_{lab} * \text{cov}(V_G, V_{lab}) / \text{var}(Z)$	0.023	-0.004
$2 * \hat{b}_{const} * \hat{b}_{lab} * \text{cov}(V_{const}, V_{lab}) / \text{var}(Z)$	-0.028	0.002
R^2	0.851	0.878
$\text{var}(\text{error}) / \text{var}(Z)$	0.149	0.122

* The $\hat{b}$'s are the coefficient values in equations (19) and (20).

Chart A1. Effect of recession on industry outputs 2008-15 (percentage of one year's output): model results versus fitted values from equation (19)

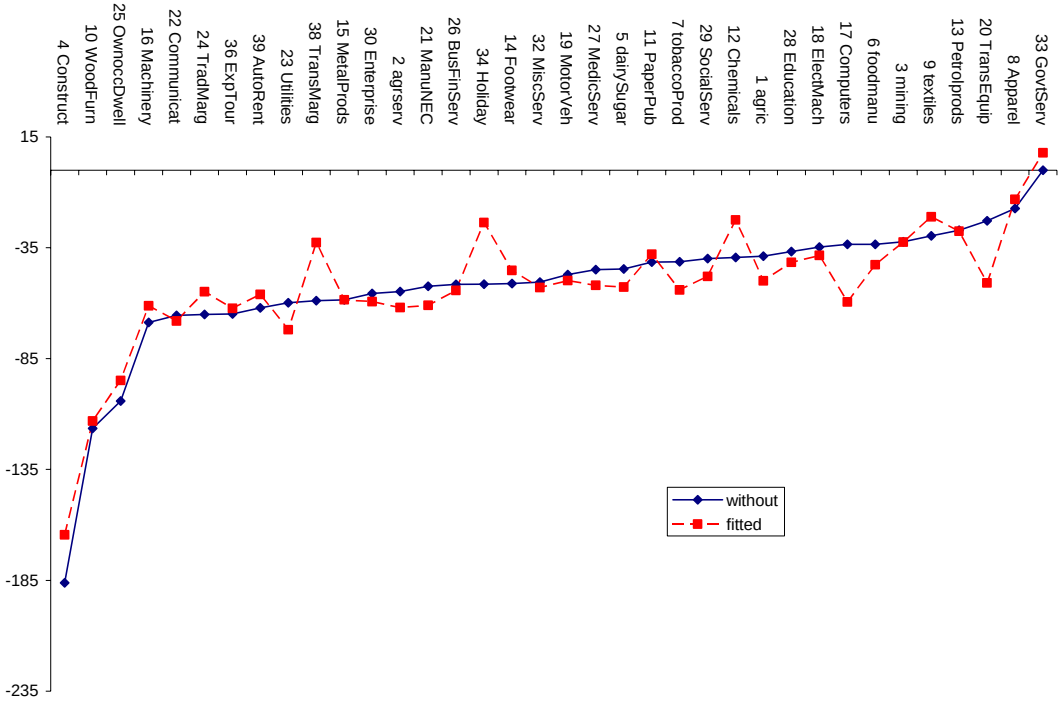

Chart A2. Effect of Obama package on industry outputs 2008-15 (percentage of one year's output): model results versus fitted values from equation (20)