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THE US ECONOMY FROM 1992 TO 1998:
RESULTS FROM A DETAILED
CGE MODEL

by

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The Centre of Policy Studies (COPS) is a research centre at Monash University devoted to quantitative analysis of issues relevant to Australian economic policy.

Abstract

This paper describes historical and decomposition simulations undertaken for 1992 to 1998 with a 500-sector CGE model of the US. The historical simulation provides estimates of movements in unobservable technology and preference variables. The decomposition simulation explains developments in the US economy in terms of movements in these variables and in observable exogenous variables such as tariffs. Both simulations produce many results. Here we use decomposition results to show that rapid growth in US international trade is explained mainly by technology changes that reduced costs in export-oriented industries and increased inputs of commodities are heavily imported.

Key words: technological change, preference change, trade growth, dynamic CGE modelling, US structural change

JEL classification numbers: C68, D68, F14

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by

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April 26, 2004

Short title: The US economy from 1992 to 1998

I. Introduction

Between 1992 and 1998, US international trade grew rapidly relative to GDP. We explain this, and other changes in the US economy from 1992 to 1998 by applying USAGE¹, a detailed dynamic computable general equilibrium model. In doing so we use naturally exogenous variables as explanators.

The difficulty is that some of the naturally exogenous variables (e.g. household preferences and industry technologies) that might affect historical outcomes are not observable. We overcome this difficulty by first conducting an historical simulation. In the historical simulation we exogenize all variables that have been observed across the period 1992 to 1998, regardless of whether they are naturally exogenous or naturally endogenous, and we shock them with their actual movements. At the same time, we endogenize naturally exogenous but unobservable variables. USAGE then produces estimates of their movements across the period. Having completed the historical simulation, we conduct a decomposition simulation. In the decomposition simulation we use the estimates of unobservable naturally exogenous variables together with data on observable naturally exogenous variables (e.g. tariff rates), to explain changes in the US economy from 1992 to 1998.

Section II describes the historical closure (set of exogenous variables) of USAGE used in estimating changes in technologies and preferences and the decomposition closure

* We thank Steve Dowrick for helpful comments.

¹ USAGE is a 500 industry, dynamic, computable general equilibrium (CGE) model of the US developed by the Centre of Policy Studies (CoPS) in collaboration with the US International Trade Commission (ITC). It is based on the MONASH model of Australia (see Dixon and Rimmer, 2002).

used in explaining structural developments including growth in trade. Sections III and IV describe our historical and decomposition results. Concluding remarks are in section V.

II. Historical and decomposition closures of USAGE

In describing historical and decomposition closures, we start by representing USAGE for any year as

$$F(X) = 0 \tag{1}$$

where F is an m -vector of differentiable functions of n variables X , and $n > m$. X includes prices and quantities for a given year and the m equations impose the usual CGE conditions such as: demands equal supplies; demands and supplies reflect optimising behaviour; prices equal unit costs; and end-of-year capital stocks equal depreciated opening capital stocks plus investment.

In applying USAGE we have available a solution (X_{initial}) of (1) derived mainly from input-output data for a particular year. In simulations, we compute the movements in m variables (endogenous) away from their values in the initial solution caused by movements in the remaining $n - m$ variables (exogenous) away from their values in the initial solution. In the simulations considered here, the initial solution is for 1992 and the movements in the exogenous variables are changes over the six years to 1998. Thus, the movements in the endogenous variables refer to the six-year period 1992 to 1998.

USAGE allows many closure choices, that is choices of the $n - m$ variables to be treated exogenously. In a decomposition closure we set as exogenous all variables not normally explained in a CGE model. These may be observables such as tax rates or unobservables such as technology and preference variables. In an historical closure the main criterion for exogeneity is observability. We exogenize a wide array of macro and industry variables for which movements can be readily obtained from statistical sources.

With reference to any pair of historical and decomposition closures, we can partition USAGE variables into four categories: (a) exogenous in both ; (b) endogenous in both; (c) exogenous in historical and endogenous in decomposition; and (d) exogenous in decomposition and endogenous in historical.

As indicated in Table 1, variables in category (a) include population size, foreign currency prices of imports and policy variables. Their values are observable and not normally explained in CGE models.

Table 1. Categories of Variables in the Historical and Decomposition Closures

(a) Exogenous in both historical and decomposition		
Population		
C.i.f. import prices in foreign currency		
Policy variables, e.g. tariff rates		
(b) Endogenous in both historical and decomposition		
Demands for intermediate inputs and margin services		
(c) Exo in historical & Endo in decomposition	(d) Exo in decomposition & Endo in historical	
i	Real private consumption by commodity	Shifts in household preferences
ii	Real imports by commodity	Domestic/import biases in preferences
iii	Real exports by commodity	Shifts in foreign demand curves
iv	Employment by industry and capital inputs by industry	Primary-factor-saving technical change, and capital/labour bias in technical change
v	Output by commodity	Commodity-using technical change in production and capital creation
vi	Real private and public investment	Investment/capital ratios

Examples of category (b) variables are demands for intermediate inputs and demands for margins services (e.g. transport) to facilitate commodity flows from producers to users. In the absence of end-of-period input-output tables, movements in these variables are not observable but are explained in CGE models.

Category (c) variables include, at the industry/commodity level, outputs, employment, capital, investment, exports, imports, private consumption and various price deflators. Also included in (c) are numerous macro variables, e.g. the exchange rate and the average wage rate. CGE models normally explain the effects on these variables of policy changes and

technology or other changes in the economic environment. At the same time, their values are observable.

Category (d) contains the same number of variables as category (c) with each variable in (c) having a corresponding variable in (d). These corresponding variables are predominantly unobservable technological and preference variables. Such variables are not normally explained by CGE models and are therefore exogenous in the decomposition closure. However in the historical closure they are endogenous, giving USAGE enough flexibility to explain the observed movements in the category (c) variables. Table 1 shows examples of corresponding pairs from (d) and (c). As indicated there, in our historical simulation we use shifts in household preferences to accommodate observations on consumption by commodity, biases in import-domestic preferences to accommodate observations on import volumes, etc.

Having allocated the USAGE variables to the four categories, we can compute historical and decomposition solutions, starting with the historical solution of the form:

$$X(\bar{H}) = G^H(X(H)) \quad (2)$$

where $X(H)$ and $X(\bar{H})$ are the exogenous and endogenous variables in the historical closure and G^H is the solution function. By observing $X(H)$ for two years, s and t , we can use (2) to estimate percentage changes between s and t , $x_{st}(\bar{H})$, in the variables in $X(\bar{H})$. Thus we combine disaggregated information [movements in the $X(H)$ variables] with a CGE model to estimate movements in a wide variety of technological and preference variables [category (d)], together with movements in more standard endogenous variables [category (b)].

Next we move to the decomposition closure which gives a solution of the form

$$X(\bar{D}) = G^D(X(D)) \quad (3)$$

where $X(D)$ and $X(\bar{D})$ are the exogenous and endogenous variables in the decomposition closure. Following the method pioneered by Johansen (1960), we express (3) in percentage change form as

$$x(\bar{D}) = B x(D) \quad (4)$$

where $x(\bar{D})$ and $x(D)$ are vectors of percentage changes in the variables in $X(\bar{D})$ and $X(D)$, and B is an m by $(n-m)$ matrix in which the ij -th element is the elasticity of the i -th component of $X(\bar{D})$ with respect to the j -th component of $X(D)$, that is

$$B_{ij} = \frac{\partial G_i^D(X(D))}{\partial X_j(D)} \frac{X_j(D)}{X_i(\bar{D})} . \quad (5)$$

With the completion of the historical simulation, the percentage changes in all variables are known. In particular the vector $x(D)$ is known. Thus we can use (4) to compute values for $x(\bar{D})$ for s to t .

We work with (4) rather than (3) because (4) gives a decomposition of the percentage changes in the variables in $X(\bar{D})$ over s to t into the parts attributable to movements in the variables in $X(D)$. This is a legitimate decomposition to the extent that the variables in $X(D)$ are genuinely exogenous, that is, vary independently of each other. In setting up the decomposition closure, the exogenous variables are chosen with this property in mind. Thus, in $X(D)$ we find policy variables, technology and preference variables and international variables all of which can be considered as independently determined and all of which can be thought of as making their own contributions to movements in endogenous variables such as incomes, consumption, exports, etc. Via (4), we can compute the contribution of the movement in the j th exogenous variable to the percentage movement in the i th endogenous variable as

$$\text{cont}_{ij} = B_{ij} * x_j(D) . \quad (6)$$

Because (3) is a non-linear system, the effect on endogenous variable i over the period s to t of movements in exogenous variable j cannot be computed unambiguously. The effects of movements in an exogenous variable depend on the values of other exogenous variables. In terms of (6), the problem is to decide at which values of the exogenous variables to evaluate B_{ij} . In the decomposition analysis in section IV, we use a procedure (Harrison *et al.*, 2000) which, in effect, evaluates B_{ij} as the average of the values generated as we move the

exogenous variables in the decomposition simulation in small steps along a straight line from their values in s to their values in t .

III. Historical simulation for 1992 to 1998

Detailed results from our 1992 to 1998 historical simulation are in Dixon and Rimmer (2003). Here we discuss results for the variables listed in category (d) of Table 1. They are 500-order industry/commodity variables that are naturally exogenous, and hence exogenous in the decomposition simulation reported in section IV, but are not readily observable, and hence endogenous in the historical simulation.

(i) Household preferences

In USAGE, the household sector is assumed to allocate its budget between commodities $i \in \text{COM}$ according to a utility-maximising specification. The resulting household demand equations are of the form:

$$X(i)/Q = G_i(C/Q; P(j), j \in \text{COM}) \quad , i \in \text{COM} \quad (7)$$

where

$X(i)$ is household consumption of commodity i ;

Q is the number of households;

$P(j)$ is the price to households of a unit of commodity j ; and

C is the household budget.

Allowing for shifts in household preferences (changes in the demand functions G_i), (7) can be expressed in percentage change form as:

$$x(i) - q = \text{EPS}(i) * (c - q) + \sum_{j \in \text{COM}} \text{ETA}(i, j) * p(j) + \text{acom}(i) \quad , i \in \text{COM} \quad (8)$$

where

$x(i)$, q , c , and $p(j)$ are percentage changes in variables denoted by the corresponding uppercase symbols;

$\text{EPS}(i)$ is the expenditure demand elasticity for good i ;

ETA(i,j) is the elasticity of demand for good i with respect to changes in the price of j; and

acom(i) is the percentage change in household preference for commodity i.²

In (8), the preference variable acom(i) acts like a residual. Its value is the difference between the *actual* percentage change in consumption of commodity i per household and the percentage change *implied* by our theory, given by the first two terms on the RHS of (8). With known movements in household consumption, prices, budget and numbers for 1992 to 1998, (8) is used in the historical simulation to estimate percentage shifts in household preferences, the acom(i)s.

Our historical results for the acom(i)s showed that there was increasing interest between 1992 and 1998 by US households in health and lifestyle issues. There were strong shifts in household preferences against Cigarettes, Malt beverages, Wine and spirits, and Distilled liquors. Lifestyle items such as Boats, Luggage, Travel trailers, Sporting clubs and Cable TV all had positive preference shifts. Fashion changes left Bowling centres and Newspapers with negative preference shifts.

(ii) Import-domestic biases in preferences

In simplified form and allowing for an import/domestic bias in preferences, the percentage change in the ratio of the demands for imported and domestic commodity i is given in USAGE by :

$$ximp(i) - xdom(i) = -\sigma(i) * [pimp(i) - pdom(i)] + twist(i) \quad (9)$$

where

ximp(i) and xdom(i) are percentage changes in demands for imported and domestic i;
pimp(i) and pdom(i) are the percentage changes in prices of imported and domestic good i;

² A budget-share weighted sum of the acom(i)s is constrained to be zero. This ensures that the household budget is satisfied.

$\sigma(i)$ is a positive parameter (the elasticity of substitution between imported and domestically produced i) controlling the responsiveness of the import/domestic mix to changes in relative prices; and

$\text{twist}(i)$ is an import-domestic preference bias variable allowing for *cost neutral* changes in preferences between imported and domestically produced good i .³

In our historical simulation $\text{twist}(i)$ is endogenous. Its value is the difference between the actual percentage change in the import/domestic ratio and the percentage change implied under our theory, the first term on the RHS of (9).

For the period 1992 to 1998, we found that import-domestic biases were in favour of the imported variety for some commodities and the domestic variety for others. For footwear commodities there were large twists in preferences towards imports and for computer commodities there were large twists against imports. Overall there was a small twist in favour of imports.

(iii) Positions of foreign demand curves for US products

In USAGE, foreign demands for US products are modelled as depending on their foreign currency prices. In historical simulations, variables representing shifts in the positions of foreign-demand curves are used to accommodate the difference between the actual percentage change in exports of commodity i and the percentage change implied by our theory (movements along foreign demand curves).

For most commodities, there were upward shifts in foreign-demand curves between 1992 and 1998. The major exceptions were computer commodities, showing sharp downward movements in foreign demand curves. With world prices of computers plummeting, the historical simulation shows that if US export prices had been held constant, then US computer exports would have been severely reduced.

³ The cost neutrality of $\text{twist}(i)$ is imposed by including twist terms in the demand equations for both domestic and imported goods. Specifically, we add $+ S_m(i)*\text{twist}(i)$ to domestic demands and $- S_d(i)*\text{twist}(i)$ to imported demands where $S_d(i)$ and $S_m(i)$ are the shares of domestic and imported good i in overall demand for good i . In this way a share-weighted sum of domestic and imported good i is free of a twist terms:

$$S_d(i) * [S_m(i) * \text{twist}(i)] + S_m(i) * [-S_d(i) * \text{twist}(i)] = 0 .$$

(iv) Capital-labour biases in technology

Capital-labour biases in technology act in a similar way to import-domestic biases (twists) in preferences. They account for the difference between the actual percentage change in the capital/labour ratio in industry j and the percentage change explained by the movements in the unit costs to j of using capital and labour.

From 1992 to 1998 there was an overall small twist in technology in favour of labour, against capital.

(v) Primary-factor-saving technical change and commodity-using technical change

In USAGE, the primary-factor-saving technical change variable for industry j accounts for the difference between the actual percentage change in primary factor input to industry j and the percentage change in j 's output.⁴ Commodity- i -using technical change accounts for the difference between the actual percentage change in the sales of commodity i to US industries and the percentage change explained by movements in production and capital-creating activities of industries that use i .⁵

The results from the historical simulation imply technological progress (reductions in overall inputs per unit of output) in the production of 410 out of the 503 USAGE commodities. For 232 commodities, technical progress was more than 5 per cent and for 8 commodities it exceeded 20 per cent. Five commodities with very rapid technical progress (>20 per cent) were in the computer equipment area. Reflecting the introduction of computer-assisted transfers of financial securities, security brokers also showed very rapid technical progress. For 93 commodities, the historical results indicated technical regress. In some cases, e.g. Bowling centres, this may reflect sluggish adjustment, especially of capital. Between 1992 and 1998, output and employment in Bowling centres declined but capital stock was almost constant. In other cases, e.g. Child day care and State and local government

⁴ Primary factor input is a CES combination of labour, capital and land. It combines with commodity inputs under a Leontief production technology to produce output. This means that while the composition of primary factor input is sensitive to factor prices, overall primary factor input is not.

⁵ We offset cost increases in industry j due to commodity-using technical change that favours the use of commodity i by imposing cost-neutralising reductions in all of j 's inputs.

health, technological regress may have resulted from increasing complexity of service provision (such as greater legal requirements and proliferating variety) leading to increases in labour and capital requirements per unit of service provided.

The commodities whose use was most strongly stimulated by technical change were computer equipment products and computer services. Various types of business services were also strongly stimulated by input-using technical change e.g. Personnel supply, Job training, Management services and Other business services.

Among the commodities that faced technologically induced demand losses were Glass, Sawmill products and Brick and clay tiles. By contrast, Concrete products and Ready-mix concrete experienced technologically induced demand gains. It appears that between 1992 and 1998, US building methods became more basic rather than artistic.

Another technological loser was Water transport. This may reflect two factors: improvements in container packing procedures and miniaturisation of products such as computers. Both these factors have the effect of reducing water transport services per unit of trade.

(vi) Investment-capital ratios

Between 1992 and 1998, investment in most industries grew rapidly relative to capital stock. Consequently, for most industries our historical simulation generated a strongly positive value for the percentage change in the investment/capital ratio.

IV. Decomposition simulation for 1992 to 1998

Having completed the historical simulation, we now adopt the decomposition closure in which technology and preference variables are exogenous. By setting these variables at their values estimated from the historical simulation, we obtain results in the decomposition simulation for output, employment and other endogenous variables identical to those in the historical simulation. However, with technology and preference variables exogenous in the decomposition simulation we can answer questions about the effects of changes in these variables. More generally, we can decompose history into the parts attributable to changes in variables such as those identified in the column headings of Table 2.

We present our decomposition analysis in three subsections. The first provides necessary background on the macroeconomic assumptions underlying the decomposition simulation. The second explains the results in Table 2 column by column. In the third we look across the columns to provide a case study that identifies factors underlying growth in US trade.

(i) Macroeconomic assumptions in the decomposition simulation

For understanding the results in Table 2, it is useful to work through Figure 1. This is a flow diagram for a one-commodity CGE model.

Exogenous variables in the decomposition closure are represented by rectangles while endogenous variables are shown in ovals. The change in aggregate employment between 1992 and 1998 (ΔL), for example, is exogenous. Thus we assume that changes in technology (ΔTECH) and changes in other exogenous variables between 1992 and 1998 did not effect aggregate employment in 1998. As is conventional in macro modelling, we assume that employment effects are eliminated over the medium term by adjustments in wage rates.

Lines (1), (2) and (3) in Figure 1 impose a production function: the change in output (ΔGDP) between 1992 and 1998 is a function of ΔTECH , ΔL and the change in capital (ΔK).

We assume that capital earns the value of its the marginal product, i.e. MPK is the ratio of the capital rental price to the price of the product. In a one-commodity model, the product price represents the asset price of capital. Consequently, MPK is the rate of return (ROR). Under constant-returns-to-scale, MPK is a function of K/L and TECH . Thus, ΔK is determined by ΔL , ΔTECH and ΔROR [lines (4), (5) and (6)].

As indicated in the figure, in our decomposition simulation ΔROR is exogenous. In analysing the effects of particular shocks over periods as long as six years (1992 to 1998) it is conventional to assume that capital adjusts to restore rates of return.

With capital earning the value of its marginal product, labour also earns the value of its marginal product. Thus, via the factor-price frontier (the relationship between MPK , MPL and TECH), ΔROR and ΔTECH determine the real wage rate [lines (16) and (17)].

We link investment in 1998 to capital in 1998 [line (7)].⁶ In isolating the effects of changes in technology etc., we assume that such changes have no impact on business confidence. Thus we treat the investment/capital ratio (a reflection of business confidence) as exogenous.

Lines (8) and (9) encapsulate the change in gross national product (ΔGNP) between 1992 and 1998. This is ΔGDP less the change in net interest/dividend payments to foreigners (a proportion of the change in net foreign liabilities, ΔNFL).

We assume in line (10) that changes in private and public consumption (ΔC , ΔG) are exogenously given proportions of ΔGNP . With ΔGDP , ΔC , ΔG and ΔI now determined, the change in the balance of trade (ΔBOT) is a residual.

Line (11) links accumulated excess savings ($S_{92/98}$) to ΔGNP . $S_{92/98}$ is the difference between the value of accumulated saving over the period 1992 to 1998 and the value it would have had in the absence of any change over this period in GNP. In deriving the link between $S_{92/98}$ and ΔGNP , we assume that saving in each year between 1992 and 1998 is a fixed proportion of GNP. A smooth growth assumption applied to GNP makes accumulated excess saving a function of ΔGNP .

The excess cost of investment between 1992 and 1998 ($I_{92/98}$) is the difference in the value of accumulated investment and the value it would have had in the absence of any change in capital (ΔK). By again invoking a smooth growth assumption, we specify $I_{92/98}$ as a function of ΔK [line (12)].

The final set of relations in Figure 1, lines (13), (14) and (15), determine ΔNFL as $I_{92/98}$ minus $S_{92/98}$ plus momentum (ΔU). Momentum is the change in NFL which would have occurred in the absence of excess accumulated savings and investment, that is the change that would have occurred with $\Delta\text{GNP} = \Delta\text{K} = 0$. Momentum consists of accumulated interest

⁶ Exogenization of ROR ties down capital stocks in 1998. This ties down aggregate investment *between* 1992 and 1998, but not *in* 1998.

payments between 1992 and 1998 on NFL of 1992 *plus* depreciation investment (accumulated investment with $\Delta K = 0$) *minus* static saving (accumulated saving with $\Delta GNP = 0$).

(ii) Decomposition simulation: macro results

The last column in Table 2 shows macro outcomes for the period 1992 to 1998. Columns 1 to 8 decompose these outcomes via (4) with the closure illustrated in Figure 1.

Column 1: momentum

Column 1 shows momentum effects, i.e. what would have happened to the US economy between 1992 and 1998 with no changes in other exogenous variables.

With ΔL , $\Delta TECH$ and ΔROR fixed at zero in the momentum column, Figure 1 indicates that there should be no change in capital, investment and GDP. That there are small changes in investment and GDP and a larger change in capital reflects structural effects (to be discussed shortly) not captured in a one-commodity representation of USAGE.

Consistent with Figure 1, column 1 shows a large effect for net foreign liabilities (row 2), with significant consequences for GNP, and private and public consumption (rows 10, 11 and 12). With almost no growth in K (1.83 per cent over six years, row 6), investment expenditures would have covered little more than depreciation. US saving would have outstripped investment leading to a decline in net foreign liabilities relative to GDP (14.32 per cent), allowing increases in GNP and private and public consumption (0.80, 0.82 and 0.77 per cent) without improvements in technology or growth in labour, capital and GDP.

The structural effects in column 1 which produce changes in capital, investment and GDP follow from the GDP identity across the bottom of Figure 1. With little change in investment relative to GDP and significant increases in private and public consumption relative to GDP, the balance of trade (BOT) deteriorates (row 1). The mechanism is real appreciation (1.47 per cent, row 3) which increases imports and reduces exports. For exports we assume that the US faces downward-sloping foreign demand curves. Thus, export contraction improves the terms of trade (0.37 per cent, row 21) with a consequent fall in the

investment-goods price index (P_i) relative to the price deflator (P_g) for GDP⁷. With ROR held constant, a decrease in P_i/P_g reduces MPK:

$$\text{MPK} = \frac{\text{Rental}}{P_g} = \frac{\text{Rental}}{P_i} * \frac{P_i}{P_g} = \text{ROR} * \frac{P_i}{P_g} \quad . \quad (10)$$

With labour and technology fixed, a reduction in MPK requires an increase in capital (row 6), producing increases in GDP and investment (rows 9 and 7). The real wage rate rises (row 5) reflecting the increase in the capital/labour ratio and the consequent increase in MPL.

Column 2: shifts in foreign export demands and import prices

The second column of Table 2 shows the effects of changes in US international trading conditions. In the historical simulation we deduced shifts in the export demand curves. For imports we assume that the US is a price taker and we treat c.i.f. foreign-currency import prices as exogenous in both the historical and decomposition closures. Because our data are for f.o.b. export prices and c.i.f. import prices, column 2 captures the effects of changes in traded-goods prices on major world markets and of changes in the costs of transport services used in facilitating flows of commodities into and out of the US.

The decomposition simulation shows that shifts in export demand curves and changes in import prices were favourable to the US. This is an almost inevitable consequence of growth in the rest of the world. In column 2 these changes in international trading conditions improved the terms of trade by 18.79 per cent (row 21). As in the momentum column, the terms-of-trade improvement generates increases in capital, GDP, investment and the real wage rate (rows 6, 9, 7 and 5).

By generating an increase in the price deflator for GDP relative to the price deflator for private and public consumption (P_g / P_c), the terms-of-trade improvement causes an increase in “purchasing-power” GNP ($=\text{GNP} * P_g / P_c$) relative to real GDP. This explains the sharp increases in real private and public consumption relative to real GDP (compare rows 11 and 12 with 9). Via the GDP identity, the sharp increases in consumption, together with the

⁷ P_i/P_g falls because P_i contains import prices and P_g contains export prices.

increase in investment, leads to a deterioration in the real balance of trade (row 14 less 13), facilitated by real appreciation (row 3). This deterioration is offset by the terms-of-trade improvement, leaving the change in the nominal balance of trade slightly positive (row 1).

Consistent with the standard two-good trade model, the improvement in the terms of trade produces an increase in imports, a relatively small change in exports (here negative) and an overall increase in trade (rows 13 – 16).

Column 3: changes in protection

Between 1992 and 1998, there were small reductions in most tariffs. As shown in column 3, these had only minor macroeconomic effects.

Reductions in protection, stimulated imports and exports (rows 13 and 14). Export expansion caused a reduction in the terms of trade (row 21) leading to a contraction in consumption (rows 11 and 12).

We assume that lost tariff revenue is replaced by a tax on labour. With a reduction in indirect taxes (tariffs) that fall partly on intermediate inputs, there is an decrease in the price of investment goods (P_i). In column 3 this is sufficient to reduce P_i / P_g despite terms-of-trade deterioration. With the rate of return fixed, there is a decrease in MPK [see (10)] with associated increases in the capital/labour ratio and the real pre-tax wage rate (rows 6, 8 and 5). Because labour is fixed, capital increases, explaining the increases in GDP (row 9) and investment (row 7).

Column 4: technical change

The macro effects of the combined movements in technology variables (primary-factor-saving technical change, input-using technical change and capital/labour bias in technical change) are shown in column 4. Overall, technology improved. With fixed labour and rate of return, this increased real wages (8.90 per cent). It also increased GDP (6.67 per cent), directly via the production function (line 2, Figure 1) and indirectly via increases in capital (lines 5 and 3). The increase in capital (1.11 per cent) was subdued relative to the increase in GDP because technology twists (biases) favoured labour. With technical change having only a minor impact on capital, net foreign liabilities are reduced (row 2). The extra

investment induced by technical change over the period 1992 to 1998 was outweighed by the extra induced savings.

Imports and exports increase sharply relative to GDP (rows 13 – 16). The increase in exports causes a decline in the terms of trade, explaining the reductions in private and public consumption relative to GDP. Investment also declines relative to GDP, reflecting subdued growth in capital. The declines in C, G and I relative to GDP explain the movement in BOT towards surplus and the declines in the real and nominal exchange rates.

Technology changes were strongly trade-favouring for two reasons: (a) export-oriented industries experienced the largest increases in total factor productivity; and (b) the movements in technology happened to favour the use of inputs that are heavily imported, particularly computers.

Column 5: changes in import/domestic preferences

Import/domestic twists increased imports by 2.8 per cent (row 13, column 5). With labour, the rate of return and technology held constant, there is little effect on capital and investment. With little impact on investment there is little impact on the balance of trade (row 1). Thus the increase in imports is accompanied by an increase in exports requiring real devaluation. The percentage increase in export volumes exceeds that in import volumes because export expansion causes a decline in the terms of trade. This reduces purchasing-power GNP leading to reductions in real private and public consumption.

Via (10), the terms-of-trade decline causes MPK to rise, thereby reducing MPL and the real wage rate. With an increase in MPK, there are small decreases in capital and investment.

Column 6: changes in consumer preferences

Column 6 shows that the macroeconomic effects of household preference shifts were small.

Because production of cigarettes and other commodities suffering adverse shifts is capital intensive relative to production of travel trailers and other commodities enjoying favourable shifts, we find small reductions in capital, investment and GDP.

Cigarettes are heavily taxed. Shifts in consumption against heavily taxed commodities tend to reduce GDP. This explains the relatively large GDP reduction (0.49 per cent)⁸. Another effect of the preference shift away from heavily taxed goods is an increase in the real pre-tax wage rate.

A final interesting feature of the preference changes is that they favoured commodities that happened to be intensively imported. This explains the increase in imports in row 13. With private and public consumption and investment all falling by about the same percentage as GDP, and with imports increasing, exports must increase (row 14), generating a reduction in the terms of trade.

Column 7: employment growth

Between 1992 and 1998, labour grew by 13.7 per cent. With constant returns to scale, fixed rates of return, fixed investment/capital ratios and no change in technology, we would expect the system depicted by lines (1) - (7) and (16) - (17) in Figure 1 to transform a 13.7 per cent increase in employment into 13.7 per cent increases in capital, investment and GDP with no change in the real wage rate. However, a larger domestic economy produces more exports with an associated decline in the terms of trade. This increases P_i/P_g , restricting the increases in capital and GDP to 12.59 and 13.53 per cent [see (10)]. With a reduction in the capital/labour ratio, there is a reduction in MPL and in the real wage rate.

Terms-of-trade deterioration limits the growth in private and public consumption to well below that of real GDP. Another limiting factor is accumulation of net foreign liabilities, reflecting rapid growth in capital. The increase in net foreign liabilities restricts consumption by restricting the growth in real GNP.

With subdued growth in private and public consumption relative to GDP, column 7 shows an 11.4 percentage point gap between export and import growth, facilitated by real devaluation.

⁸ With the capital share in GDP being 30 per cent, the reduction in capital suggests a GDP reduction of about 0.22 per cent.

Column 8: other factors

With decomposition simulations we can look at the effects of an overwhelming number of exogenous variables. Inevitably, we must terminate the process by having an “other column”, here column 8.

The main shocks in column 8 are to macro ratios. Recall from lines (7) and (10) in Figure 1 that in the decomposition simulation we exogenize investment/capital ratios and the average propensities to consume (C/GNP, G/GNP). In columns 1 to 7, these ratios were fixed. In column 8 we introduce, as exogenous shocks, the changes in the ratios that were endogenously determined in the historical simulation.

For most sectors, the investment/capital ratio was higher in 1998 than in 1992, explaining the strongly positive result for real investment (row 7). The C/GNP ratio was higher in 1998 than in 1992, explaining the positive result for real private consumption (row 11), but the G/GNP ratio fell, explaining the negative result in row 12. Overall there was a slight fall in total consumption (private and public) relative to GNP. This was easily outweighed by the increase in investment relative to GNP. Thus we find a strong movement to balance-of-trade deficit (row 1), facilitated by real appreciation (row 3). Real appreciation explains sharp contraction in exports (row 14), improvement in the terms of trade (row 21) and expansion in imports (row 13).

Column 8 shows a reduction in net foreign liabilities as a per cent of GDP (row 2). As well as changes in macro ratios, column 8 includes the effects of the overall increase in the price level (a 11.41 per cent increase in P_C , row 18). Because a considerable fraction of US foreign liabilities is repayable in US dollars, general domestic inflation has the effect of reducing US foreign liabilities relative to GDP.

(iii) Cross-column analysis: growth in US trade between 1992 and 1998

Why did US trade grow so fast between 1992 and 1998?

The final entry in row 16 of Table 2 shows that trade as a share of GDP increased by 37.16 per cent. Well over half of this (20.62 percentage points) was contributed by technology. As explained in our discussion of column 4, technological change was strongly

trade-favouring because total-factor-productivity growth was relatively rapid in export-oriented industries and movements in technology favoured the use of inputs that are heavily imported, particularly computers.

The second largest entry in row 16 is for changes in trading conditions (6.38 percentage points, column 2). To a large extent, this entry gives the effects on US trade of growth in the rest of the world. With growth in the world economy, the US benefited from outward shifts in foreign demand curves for its exports and from outward shifts in foreign supply curves for its imports. These demand and supply shifts generated a sharp improvement in the US terms of trade. This was trade expanding because it allowed strong import growth with only a small contraction in exports.

Twists in industry and household preferences towards imports (column 5) and changes in household preferences between commodities (column 6) each contributed about 4 percentage points to growth in the trade/GDP ratio. Preference twists towards imports directly increased imports and indirectly increased exports via real devaluation. Changes in household preferences stimulated trade by increasing demand for some commodities that are heavily imported (e.g. computer products) while decreasing demand for some other commodities that are lightly imported (e.g. cigarettes).

The remaining entries (those in columns 1, 3, 7 and 8) in row 16 have absolute values of less than one percentage point. These entries include the effects of tariff reductions, often cited as a major cause of trade growth. However, for the US between 1992 and 1998 their contribution to growth in the trade/GDP ratio was only 0.87 percentage points. As mentioned in our discussion of column 3, tariff cuts over this period were small.

V. Concluding remarks

In this paper we have explained developments in the US economy between 1992 and 1998 via a USAGE decomposition simulation. Important driving factors in the explanation were changes over the period in naturally exogenous, but unobservable, technology and preference variables. Changes in these variables were estimated in an historical simulation.

As well as providing a key ingredient in decomposition simulations, historical simulations have two other roles.

The first is in providing up-to-date input-output tables. The most recent US input-output table available in 2000 when we started work on USAGE was for 1992. Policy analysis based on outdated data is too easily dismissed by critics and may sometimes genuinely miss important aspects of the issue under investigation. For example, an analysis of the stevedoring industry based on 1992 data would underestimate the benefits of cost-reducing reforms by understating the current importance in the US economy of international trade. In forecasting, up-to-date input-output data are an unavoidable requirement if we want to say anything about likely developments in business-cycle-related variables. By generating prices and quantities for all input-output flows, historical simulations can be used to provide an updated input-output table for a recent year incorporating observed movements in: industry and commodity outputs; prices and quantities for exports and imports; quantities for private and public consumption; and quantities for capital, investment and employment by industry. The historical simulation discussed in this paper generates input-output data for 1998. We are currently working on another historical simulation that will produce input-output data for 2002.

The second role of historical simulations is in providing a basis for forecasting trends in detailed technology and preference variables. Settings for these variables in forecast simulations are made by extrapolating their estimated values from an historical simulation. In this way forecast simulations are given industrial detail that is plausible in light of the historical record.

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Table 2. Macroeconomic variables: Decomposition of changes from 1992 to 1998

	1	2	3	4	5	6	7	8	Total	
	Momentum	Shifts in foreign demands & import prices	Changes in tariffs	Technical change	Changes in import/domestic preferences	H'hold tastes	Growth in employment	Other factors		
1	Change in balance of trade, % of GDP	-0.21	0.57	-0.01	0.79	-0.07	-0.02	0.46	-2.64	-1.13
2	Change in net foreign liabilities, % of GDP	-14.32	6.30	0.25	-0.08	-2.53	-2.37	31.79	-9.11	9.94
Percentage changes										
3	Real exchange rate	1.47	24.66	-0.49	-6.49	-2.55	-0.83	-7.77	7.81	15.82
4	Nominal exchange rate	1.30	31.59	-0.45	-4.92	-2.32	-0.86	-6.97	-3.84	13.53
5	Real wage rate (P _g deflated)	1.32	3.13	0.18	8.90	-0.16	0.12	-0.68	-2.28	10.55
6	Capital stock (K)	1.83	4.75	0.10	1.11	-0.95	-0.67	12.59	-1.19	17.57
7	Real investment (I)	0.60	5.65	0.12	5.41	-1.05	-0.61	14.04	24.85	49.01
8	Employment (L)	0.00	0.00	0.00	0.00	0.00	0.00	13.70	0.00	13.70
9	Real GDP	0.48	2.09	0.03	6.67	-0.64	-0.49	13.53	-1.21	20.45
10	Real GNP (P _g deflated)	0.80	1.94	0.03	6.63	-0.59	-0.44	12.82	-1.00	20.19
11	Real private consumption (C)	0.82	3.96	-0.03	4.43	-0.80	-0.47	12.27	1.43	21.61
12	Real public consumption (G)	0.77	3.58	-0.03	3.93	-0.74	-0.43	11.35	-14.96	3.48
13	Imports, volume	1.85	18.77	0.66	15.58	2.80	2.64	8.81	16.67	67.76
14	Exports, volume	-1.01	-1.83	1.13	38.99	4.92	3.43	20.21	-18.40	47.45
15	Total trade, volume	0.42	8.47	0.90	27.29	3.86	3.04	14.51	-0.86	57.61
16	Trade/GDP	-0.06	6.38	0.87	20.62	4.50	3.53	0.98	0.35	37.16
17	GDP price deflator (P _g)	0.20	2.39	-0.04	-1.57	-0.25	0.03	-0.83	11.74	11.66
18	Price deflator for consumption (P _c)	0.18	0.52	0.02	0.67	-0.05	0.05	-0.18	11.41	12.62
19	Price deflator for investment (P _i)	0.02	-3.68	-0.05	-3.39	0.20	0.38	0.55	8.27	2.30
20	Price deflator for public consumption	0.90	2.61	0.10	3.35	-0.24	0.24	-0.91	7.28	13.32
21	Terms of trade	0.37	18.79	-0.34	-10.87	-2.04	-0.54	-5.74	5.68	5.31