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Short Run Global Effects of US “New Economy” Shocks: the Role of Capital-Skill Complementarity*

Rod Tyers
Australian National University

Yongzheng Yang**
International Monetary Fund

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Abstract

Long run technical change since the 1970s can be characterised alternatively as capital enhancement when capital and skill are complementary, or skill enhancement when capital and skill are substitutes. These characterisations are not equivalent in the short run, however, particularly in the capital-mobile late 1990s, because the implications of the shocks for the return to installed physical capital, and hence the global distribution of investment, depend on which of the two is chosen. The extent of this non-equivalence is demonstrated in this paper, which examines the short run effects of the acceleration of technology shocks in the US during the late 1990s. Two comparative static multi-product macroeconomic models are constructed around the alternative characterisations and technology shocks are introduced in the US alone. A US economic expansion and gains to US factor owners are common to both but the sectoral and distributional effects within the US economy differ substantially between them. The effects on other regions follow primarily from changes in the distribution of global investment and the associated changes in real exchange rates and hence they are also sensitive to the technology characterisation chosen.

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1. Introduction

The long boom of the 1990s in the US was underpinned by strong growth in labour productivity¹, stemming at least in part from extraordinary growth in the information technology sector and the spread of its products and services throughout the economy.² This process is causing a dramatic change in the composition of the capital stock. The new information technology is declining in price relative to other capital so that its value share is rising less quickly than its productivity.³ Yet, in the US at least, there has been a substantial rise in the value share of “equipment” and a corresponding decline in the share of “structures”.⁴ Growth in the “effective” capital stock has therefore accelerated. To the extent that capital, and more particularly equipment, is complementary with skill, this is likely to explain recent growth in the skill premium in the US.⁵ Expectations associated with the information technology boom also explain a significant rise in US investment during the 1990s, financed at least in part by savings from abroad.

Insights into the technical change of this period are available from the extensive recent literature on the determinants of the relatively poor labour market performance by unskilled workers. A prevalent conclusion in that literature is that this is due to technical change and, in particular, skill-biased change associated with the introduction of information technology.⁶ One clear statement of the technical implications of this finding is by Kahn and Lim (1998). They take the view that skill and labour have a larger than unit substitution elasticity and that computer-based automation enhances skilled labour time, increasing “effective” skill hours per actual skilled worker and thereby raising the marginal product of skilled relative to unskilled workers.⁷ According to this view, the technical change acts directly to change the factor-specific parameters of the production function.

While there is ample evidence that labour and skill are substitutes, a role for capital-skill complementarity was recognised early on by Griliches (1969) and Fallon and Layard (1975). More recently, Goldin and Katz (1998), took the view that skill-capital complementarity was a key determinant of the US skill premium throughout the 20th century. This view is examined more formally by Krusell et al. (1997) who focus on the US in the period between 1963 and 1991. They conclude that the observed changes in US skill premia can be explained without resort to changes in the fundamental parameters of the production function. They formulate a simple nested CES production system that embodies capital skill complementarity and find that skill premia are explained almost entirely by readily observable

¹ See, for example, Oliner and Sichel (2000), who analysis the observed “one percentage point step-up in productivity growth between the first and the second halves of the decade” of the 1990s.

² The analysis by Oliner and Sichel (2000) accounts for the special effects of computer obsolescence highlighted by Whelan (2000) and attributes about two thirds of the half-decade productivity step-up to (i) increased output in the computer and software production industry and (ii) increased use of information technology in other sectors.

³ See Greenwood et al. (1997, 2000: Figure 1).

⁴ See Krusell et al. (1997), Figure 1.

⁵ See Krusell et al. (1997) and Tyers and Yang (2000).

⁶ Sachs and Shatz (1994) and Wood (1994), among others, find some role for trade, while Abraham and Taylor (1996) and Feenstra and Hansen (1996) focus on the contribution of out-sourcing and its associated effects on both trade and home technology. Haskel and Heden (1999) and Haskel and Slaughter (1998, 1999) emphasise the evidence favouring skill-biased technical change associated with computerisation. The dominance of the latter is confirmed for the U.S. in a more recent empirical analysis by Morrison Paul and Siegel (2000).

⁷ When substitution between labour and skill is elastic, the unit isoquant is drawn further inward the more skill intensive is the technique and so, even at constant factor prices, the cost share of skill rises. The common presumption that automation enhances labour (is “labour saving”) is only consistent with a rise in the skill share if the elasticity of substitution between skill and labour is less than unity.

factor accumulation. Their results are aided by the disaggregation of the capital stock into “equipment” and “structures”, the incorporation of complementarity between equipment and skill and the implementation of shocks to both the size of the capital stock and its composition.⁸

A parallel analysis of changes in the global economy is carried out using a general equilibrium model by Tyers and Yang (2000). They construct a backcast over two decades in which observed changes in aggregate productivity and the skill premium are imposed as exogenous while technical parameters are made endogenous. This approach has the advantage that it also enables them to control for other relevant macroeconomic shocks, including changes in trade distortions and in labour market policy. For the many regions included in that study, however, data on the composition of capital stocks were unavailable. When capital-skill complementarity is incorporated into all technologies, their results therefore characterise the technical change that occurred in the last two decades as primarily “capital augmentation”, reflecting unobserved compositional changes in capital stocks. Moreover, this type of technical change is shown to have been most rapid in the US during this period.

They also compare the implied pattern of technical change when the base technology has capital-skill complementarity on the one hand and capital-skill substitution on the other. When skill and capital are represented as substitutes, the implied technical change is skill-enhancement. Although the empirical evidence tends to support the model with capital-skill complementarity,⁹ both technology characterisations could be consistent with the observed pattern of long run technical change. Where they differ, however, is in their implications for short run behaviour. Short run responses to technology shocks differ in that elasticities are smaller, physical capital is sector specific and nominal rigidities can cause employment and output fluctuations. When other conditions are constant, however, they must accumulate into the observed long run responses. But other things have not been constant in recent decades. For one thing, there is evidence that the magnitudes of annual technology shocks have enlarged. For another, capital has become more mobile internationally. When a technology shock alters the return on installed capital this changes the global pattern of investment and output more substantially than in the beginning of the period. Because the size of the change in the return on installed capital depends on the characterisation of technologies and technology shocks, these matter in the “new economy” era more than before.

In this paper we explore these short run implications by examining the simulated response of the world economy to US “new economy” shocks. In particular, we examine the global implications of a technical change shock in the US alone and then combine it with an investment shock so that the associated US expansion is financed in part from abroad, following the pattern of the late 1990s. We use a global comparative static multi-product model like that on which the long run analysis of Tyers and Yang (2000) was based but which has been adapted for short run macroeconomic analysis as in Yang and Tyers (2000). In order to focus on the contrast between capital-skill substitution and complementarity, for each region and each industry within it we depart from the traditional representation of factor demand in such models¹⁰ by constructing alternative nested CES production systems, with and without skill-capital complementarity.

⁸ This disaggregation is also used by Kahn and Lim (1998).

⁹ See, for example, Hamermesh (1993).

¹⁰ It has been the accepted practice in general equilibrium analysis to assume simple factor demand structures implying unit elasticities of substitution between capital and labour. See Shoven and Whalley (1992: 5.4) and Dixon et al. (1992: 220). For an application to labour markets, see Burfisher et al. (1994).

The model used is described in Section 2 and our construction of the alternative technologies is discussed in Section 3. The technology and investment shocks and their implications are presented in Section 4 and Section 5 concludes.

2. A Global Model for Short Run Comparative Statics

The model is adapted from a version of GTAP: a multi-region comparative static model in real variables with price-taking households and all industries comprising identical competitive firms.¹¹ This original model provides the supply side of that used here. It offers the following useful microeconomics: (1) a capital goods sector in each region to service investment, (2) explicit savings in each region, combined with open regional capital accounts that permit savings in one region to finance investment in others, (3) multiple trading regions, goods and primary factors, (4) product differentiation by country of origin, (5) empirically based differences in tastes and technology across regions, (6) non-homothetic preferences, and (7) explicit transportation costs and indirect taxes on trade, production and consumption.

All individual goods and services entering final and intermediate demand are CES blends of home products and imports. In turn, imports are CES composites of the products of all regions the content of which depends on regional trading prices. Savings are pooled globally and investment is then allocated between regions from the global pool. Within regions, investment places demands on the domestic capital goods sector, which is also a CES composite of home-produced goods, services and imports in the manner of government spending. The primary factors identified are land, natural resources, labour, skill and physical capital (Table 1). Skill is separated from raw labour on occupational grounds, with occupations in the “professional” categories of the ILO classification included as skilled.¹²

A key modification of the standard model code makes the government financially independent, and so enables more explicit treatment of fiscal policy. Direct taxes are incorporated at the observed average income tax rates for each region. Marginal tax rates are therefore assumed constant at τ . Regional households then receive regional factor income, Y_F , and from this they pay direct tax τY_F . The disposable income that remains is then divided between private consumption and private saving. Government saving, or the government surplus, $S_G = T - G$, is then simply revenue from direct taxes, τY_F , and indirect taxes, T_I , less government spending, G , which could be exogenous or fixed as a proportion of GDP.¹³ Thus, $S_G = T_I + \tau Y_F - G$. The private saving and consumption decision is represented by a reduced form exponential consumption equation with wealth effects included via the dependence of consumption (and hence savings) on the interest rate. Each region then contributes its total (private plus government) saving, $S_T = S_P + S_G$, to the global pool from which investment is derived.

For each region, the above relations imply the balance of payments identity, which sets the current account surplus equal to the capital account deficit: $X - M = S_P + S_G - I$.¹⁴ From the pool of global savings, investment is allocated across regions and places demands on regional capital goods sectors. In the short run considered, it does not add to the installed capital stock, however. Also at this length of run, nominal wages are sticky in some regions (the EU, Canada, Australasia and China) but flexible elsewhere. In the spirit of comparative

¹¹ A detailed description of the original is provided by Hertel (1997).

¹² See Vo and Tyers (1995) and Liu et al. (1998) for the method adopted.

¹³ T_I includes revenue from taxes on production, consumption, factor use and trade, all of which are accounted for in the original model and database.

¹⁴ Note that there is no allowance for interregional capital ownership in the starting equilibrium. At the outset, therefore, there are no factor service flows and the current account is the same as the balance of trade.

statics, although price levels do change in response to shocks, no continuous inflation is represented and so there is no distinction between the real and nominal interest rates.

In allocating the global savings pool as investment across regions, we have opted to use the most flexible approach, implying a high level of global capital mobility.¹⁵ The allocation ensures that the proportional change in investment is larger in regions, j , with high values of the average rate of return on installed capital, r_j^c . In this process, a global “expected return”, r^w , is calculated such that $\sum_j S_j^T = \sum_j I_j(r^w, r_j^c, \pi_j)$, where I_j is real investment in region j and π_j is a region-specific risk premium.¹⁶ The investment demand equation for region j takes the form:

$$(1) \quad \frac{K_j + I_j}{K_j} = \beta \left(\frac{1 + r^w(1 + \pi_j)}{1 + r_j^c} \right)^\varepsilon$$

where K_j is the (exogenous) installed capital stock, β is a positive constant and ε is a negative elasticity. The numerator on the right hand side is the expected gross return on investment in region j , so that $(1 + r_j) = (1 + r^w)(1 + \pi_j)$ or $r_j \approx r^w + \pi_j$.

Note that our short run comparative static analysis does not require that the global economy be in a steady state. When shocks are imposed, the counterfactual return on installed capital, r_j^c , need not be the same as the corresponding expected return on investment, r_j . Such shocks, implemented in the current period, change income and savings and, therefore, expected returns in directions that differ from the returns on installed capital, particularly considering that capital is fixed in quantity and sectoral distribution.

To include the monetary sector in each region we simply add *LM* curves. This implies that regionally homogeneous nominal bonds are the only financial assets other than regional money. Even though there is no interregional ownership of installed capital in the initial database these bonds are traded internationally, making it possible for savers in one region to finance investment in another.¹⁷ The yield on the j th region’s bonds in the single period represented by the model is the interest rate, r_j , defined above. Cash in advance constraints then cause households to maintain portfolios including both bonds and non-yielding money and the resulting demand for real money balances has the usual reduced form dependence on GDP (transactions demand) and the interest rate. This is equated with the region’s real money supply, where purchasing power is measured in terms of its GDP deflator, P^j .

Since all domestic transactions are assumed to use the home region’s money, international transactions require currency exchange. For this purpose, a single nominal exchange rate, E_j , is defined for each region. A single key region is identified (here the US) relative to whose currency these nominal rates are defined. For the US, then, $E=1$ and E_j is the number of US dollars per unit of region j ’s currency. In essence, we are adding to the real

¹⁵ By which it is meant that households can direct their savings to any region in the world without impediment. Installed capital, however, remains immobile even between sectors.

¹⁶ Before adding to the global pool, savings in each region is deflated using the regional capital goods price index and then converted into US\$ at the initial exchange rate. The global investment allocation process then is made in real volume terms.

¹⁷ Since the initial database we use (GTAP Version IV) incorporates no “net income” or factor service component in its current account, our initial equilibria must do likewise. This implies the assumption that, although there are no interregional bond holdings initially, the shocks implemented cause interregional exchanges of bonds and hence a non-zero net income flow in future current accounts not represented.

model one new equation per region (the LM curve linking the real money supply to GDP and the interest rate) and one new (usually endogenous) variable per region, E_j .¹⁸

The bilateral rate between region i and region j is then simply the quotient of the two exchange rates with the US, $E_{ij} = E_i/E_j$. Quotients such as this appear in all international transactions. The most straightforward of the international transactions in the original model are trade transactions. There the bilateral exchange rate is simply included in all import price equations, along with *cif/fob* margins and trade taxes. In the case of savings and investment, the global pool of savings is accumulated in US dollars. Investment, once allocated to region j , is converted to that region's currency at the rate E_j . The third, and most cryptic, set of international transactions in the original model concerns international transport services. Payments associated with *cif/fob* margins are assumed to be made by the importer in US dollars. The global transport sector then demands inputs from each regional economy and these transactions are converted at the appropriate regional rates.

Without nominal rigidities the model always exhibits money neutrality, both at the regional and global levels. Firms in the model respond to changes in nominal product, input and factor prices but a real producer wage is calculated for labour as the quotient of the nominal wage and the GDP deflator, so that $w = W/P^Y$. Thus, money shocks always maintain constant w when nominal rigidities are absent. It is in the setting of the nominal wage, W , that we have introduced nominal rigidities to the model. A parameter, $\lambda \in (0, 1)$ is inserted, such that

$$(2) \quad \frac{W}{W_0} = \Lambda \left(\frac{P^Y}{P_0^Y} \right)^\lambda$$

where W_0 is the initial value of the nominal wage, P_0^Y is the corresponding initial value of the GDP deflator and Λ is a slack constant. While ever Λ is exogenous and set a unity, the nominal wage carries this relationship to the price level and the labour market will not clear except in the unlikely event that equation (2) happens to yield a market clearing real wage. The case where the labour market is fully flexible is represented by setting Λ as an endogenous slack variable and thereby rendering (2) ineffective. At the same time, labour demand is forced to equate with exogenous labour supply to reflect the clearing market.

Because the length of run is short, the real part of the model incorporates smaller-than-standard elasticities of substitution in both demand and supply. The key elasticities of substitution on the demand side are listed in Table 2. These are set smaller than the standard ones to an extent guided by a short run calibration exercise on the Asian crisis, described in Yang and Tyers (2000). The representation of production technologies is discussed in Section 3, to follow.

3. Production Technology and Factor Demand

We adopt two alternative technologies, both of which are nested CES structures that differ from those in the original model. Our standard technology is a three level nest that allows the substitutability between raw labour and skill to differ from that between these and

¹⁸ More precisely, since for the US $E=1$, we are adding one less (usually endogenous) variable. Where nominal exchange rates are to be endogenous and nominal money supplies exogenous, one additional variable must be made endogenous. We could, for example, balance this by making one price level exogenous, such as by having US monetary policy target the change in the US CPI, P^C .

other factors, making it possible to vary the degree of substitutability between labour and skill without changing that between other factor pairs.¹⁹

The weak separability essential to nested CES structures allows the production function to take the following form:

$$(3) \quad Y = \alpha_Y \left[\phi_{VI} (\delta_{VI} VI)^{-\rho_Y} + \phi_{VA} (\delta_{VA} VA)^{-\rho_Y} \right]^{-\frac{1}{\rho_Y}}$$

where VI is the composite of intermediate inputs and VA is the value added composite of all primary factors, α_Y , δ_{VI} and δ_{VA} are technology shifters to be used subsequently and ϕ_{CI} and ϕ_{VA} are parameters that depend on the shares of VI and VA in total cost.²⁰ Finally, the top-level elasticity of substitution is $\sigma_Y = 1/(1 + \rho_Y)$. Following the primary factor branch of the nest, the value-added composite is then

$$(4) \quad VA = \alpha_{VA} \left[\phi_{VL} (\delta_{VL} VL)^{-\rho_{VA}} + \phi_K (\delta_K K)^{-\rho_{VA}} + \phi_R (\delta_R R)^{-\rho_{VA}} + \phi_A (\delta_A A)^{-\rho_{VA}} \right]^{-\frac{1}{\rho_{VA}}}$$

where VL is value added in labour and skill (a labour-skill composite) and the parameters play the same roles as in (1), above. The elasticity of substitution at this level is $\sigma_{VA} = 1/(1 + \rho_{VA})$. To complete the nest, then, a similar formulation is offered for the labour-skill component of value added, VL :

$$(5) \quad VL = \alpha_{VL} \left[\phi_L (\delta_L L)^{-\rho_{VL}} + \phi_S (\delta_S S)^{-\rho_{VL}} \right]^{-\frac{1}{\rho_{VL}}}$$

where L is raw labour and S is skill and the level-specific elasticity of substitution between them is $\sigma_{VL} = 1/(1 + \rho_{VL})$.

Again, the initial values of the technology shifters α and δ , are unity.²¹ The combination of (3) – (5) allows the proportional change in the demand for any factor or intermediate input, X_i , denoted lower case as x_i , to be expressed in terms of the corresponding proportional changes in output, y , and proportional changes in all of the factor prices, p_j , as

$$(6) \quad x_i = y + \sum_j \eta_{ij} p_j$$

where η_{ij} is the conditional elasticity of demand for input or factor i with respect to the price of input or factor j . These demand elasticities, $[\eta_{ij}]$, follow from the Allen partial elasticities of substitution, $[\sigma_{ij}]$ via $\eta_{ij} = \sigma_{ij} \theta_j$, where θ_j is the share of factor or input j in total cost. The Allen partials are conditional (output constant) elasticities of substitution for pairs of inputs when more than two are used and where they are combined in a multi-level nest. In the two-factor single-level case they collapse to the branch elasticity (Allen 1938: 341, Hamermesh

¹⁹ The original model has a two level structure with a Leontief split between intermediates and primary factors (value added) and labour and skill are treated in the same way as the other three factors.

²⁰ In such CES structures the number of independent parameters is equal to the number of factors or inputs. Here only the ϕ s are independent and derived from the database. The α s and the δ s are shifters set to unity unless the technology changes.

²¹ The remaining parameters are derived from the GTAP Version 4 database for each region, detailed in McDougall et al. (1998a).

1993: 23, 39). They are symmetric ($\sigma_{ij} = \sigma_{ji}$) and can be derived from the branch elasticities of substitution, σ_Y , σ_{VA} , and σ_{VL} by the method of Keller (1980: Ch.5, Appendix). Those of special interest for our present purpose are the own price elasticities for labour, η_{LL} , skill, η_{SS} and capital, η_{KK} and the associated cross price elasticities, η_{LS} , η_{SL} , η_{LK} , η_{KL} , η_{SK} and η_{KS} . The own price elasticity for labour, for example, takes the following form:

$$(7) \quad \eta_{LL} = -\theta_L [\sigma_{VL}(\theta_L^{-1} - \theta_{VL}^{-1}) + \sigma_{VA}(\theta_{VL}^{-1} - \theta_{VA}^{-1}) + \sigma_Y(\theta_{VA}^{-1} - 1)]$$

where θ_L is the share of raw labour, θ_{VL} the combined share of labour and skill and θ_{VA} the share of value added in total cost.²² And the cross elasticities between labour and skill and labour and capital are:

$$(8) \quad \eta_{LS} = \sigma_{LS}\theta_S = \theta_S [\sigma_{VL}\theta_{VL}^{-1} - \sigma_{VA}(\theta_{VL}^{-1} - \theta_{VA}^{-1}) - \sigma_Y(\theta_{VA}^{-1} - 1)]$$

$$(9) \quad \eta_{LK} = \sigma_{LK}\theta_K = \theta_K [\sigma_{VA}\theta_{VA}^{-1} - \sigma_Y(\theta_{VA}^{-1} - 1)]$$

where σ_{LS} and σ_{LK} are the Allen partial elasticities of substitution. The remaining own and cross price elasticities follow similarly.

We contrast this production structure with one that allows complementarity of capital and skill. The highest level of this alternative nest is the same as previously, with the level of output indicated by equation (3). Following the primary factor branch of the nest, the value-added composite is now

$$(10) \quad VA = \alpha_{VA} [\phi_{VKL} (\delta_{VKL} VKL)^{-\rho_{VA}} + \phi_R (\delta_R R)^{-\rho_{VA}} + \phi_A (\delta_A A)^{-\rho_{VA}}]^{-\frac{1}{\rho_{VA}}}$$

where VKL is value added in capital, labour and skill. Also as before, the elasticity of substitution at this level is $\sigma_{VA} = 1/(1 + \rho_{VA})$. The capital-labour-skill component of value added, VKL is then:

$$(11) \quad VKL = \alpha_{VKL} [\phi_{KS} (\delta_{KS} KS)^{-\rho_{VKL}} + \phi_L (\delta_L L)^{-\rho_{VKL}}]^{-\frac{1}{\rho_{VKL}}}$$

where L is raw labour and KS is a capital-skill composite. The level-specific or branch elasticity of substitution is then $\sigma_{VKL} = 1/(1 + \rho_{VKL})$. Finally, there is an additional level that divides capital and skill:

$$(12) \quad VKS = \alpha_{VKS} [\phi_K (\delta_K K)^{-\rho_{VKS}} + \phi_S (\delta_S S)^{-\rho_{VKS}}]^{-\frac{1}{\rho_{VKS}}}$$

where the branch elasticity of substitution at this lowest level is $\sigma_{VKS} = 1/(1 + \rho_{VKS})$.

In this case, the own price elasticity for capital takes the following form:

²² For a single level system in which the elasticity of substitution is σ this collapses to $-\theta_L[\sigma(\theta_L^{-1} - 1)] = -(1 - \theta_L)\sigma$, consistent with the treatment by Hamermesh (1993).

$$(13) \quad \eta_{KK} = -\theta_K \left[\sigma_{VKS} (\theta_K^{-1} - \theta_{VKS}^{-1}) + \sigma_{VKL} (\theta_{VKS}^{-1} - \theta_{VKL}^{-1}) + \sigma_{VA} (\theta_{VKL}^{-1} - \theta_{VA}^{-1}) + \sigma_Y (\theta_{VA}^{-1} - 1) \right]$$

where θ_K is the share of capital, θ_{VKS} the combined share of capital, θ_{VKL} the combined share of capital, skill and labour, and θ_{VA} is the share of value added in total cost. Since capital and skill are here treated symmetrically, the own price elasticity of demand for skill takes a corresponding form. And the cross elasticities between capital and skill and capital and labour are:

$$(14) \quad \eta_{KS} = \sigma_{KS} \theta_S = \theta_S \left[\sigma_{VKS} \theta_{VKS}^{-1} - \sigma_{VKL} (\theta_{VKS}^{-1} - \theta_{VKL}^{-1}) - \sigma_{VA} (\theta_{VKL}^{-1} - \theta_{VA}^{-1}) - \sigma_Y (\theta_{VA}^{-1} - 1) \right]$$

$$(15) \quad \eta_{KL} = \sigma_{KL} \theta_L = \theta_L \left[\sigma_{VKL} \theta_{VKL}^{-1} - \sigma_{VA} (\theta_{VKL}^{-1} - \theta_{VA}^{-1}) - \sigma_Y (\theta_{VA}^{-1} - 1) \right]$$

where, again, σ_{KS} and σ_{KL} are Allen partial elasticities of substitution. The remaining cross price elasticities follow similarly.

The branch elasticities in both the substitution and complementarity cases vary across industries by the same proportions as the “standard” set in the original GTAP Version IV database. The shorter length of run used here requires, however, that they be smaller than the standard values and so their choice has been informed both by the calibration exercise reported in Yang and Tyers (2000) and the contrasts between short and long run estimates by Morrison Paul and Siegel (2000). For the particular branch elasticities between capital, labour and skill, we note the small short run elasticities between capital and labour reviewed by Rowthorn (1999a and b) but have opted for larger values from the studies reviewed by Hamermesh (1993) and the estimates of Krusell et al. (1997), as indicated in Tables 3 and 4. The implied own and cross price elasticities are then listed in Table 5. The parameters of the macro part of the model (those in the consumption and investment demand equations and in the real money demand, or *LM*, equation) are from Yang and Tyers (2000).

4. Simulating US “New Economy” Shocks

The shocks:

The results obtained by Tyers and Yang (2000) offer two alternative characterisations of technical change in the final two decades of the 20th century. First, if technology is characterised following Kahn and Lim (1998) as embodying substitution between capital and skill, the principal technical change takes the form of skill enhancement or an increase in δ_s in equation (5). If it is characterised following Krusell et al. (1997) as embodying capital-skill complementarity, the implied technical change is capital enhancement, or an increase in δ_k in equation (12). Most economy-wide modelling assumes the former while the preponderance of empirical evidence supports the latter. Our purpose here is to ask what difference it makes in a short run setting. To do this we note from Tyers and Yang (2000) that the change was the most rapid in the US. When the base technology exhibited capital-skill complementarity, their results implied that the technical change was capital enhancement at an average rate of 1.7 per cent per year. When capital and skill were considered substitutes, however, the implied change was skill enhancement at an average rate of 3.3 per cent per year.

One approach would be to simply impose these annual averages as short run shocks. The evidence of Oliner and Sichel (2000) indicate, however, that the pace of technical change accelerated in the US in the latter half of the 1990s, with the effect of “a one per cent step-up

in aggregate labour productivity growth”. We therefore focus on a technical change shock in the US alone and the annual rates are increased to a three per cent capital enhancement in the case of capital-skill complementarity and a five per cent skill enhancement when capital and skill are substitutes. To better represent what happened in the second half of the 1990s, however, we combine this with a five per cent increase in real investment in the US. This is about the size of the step-up in US real investment in the mid-1990s, which occurred as savers worldwide were attracted to the promise of high returns in the US “new economy”.²³ Both the technology and investment shocks played key roles in the overall pattern of change in the global economy in that period. We do not, and indeed cannot in a comparative static model, endogenise the change in the locational preferences of savers that took place in the 1990s and which favoured investment in the US. Both the technical change shock and the investment shock are therefore imposed exogenously.

The closure:

Before we describe the scenarios in detail, it is useful to reflect briefly on their technical underpinnings. The model is simply a set of n non-linear simultaneous equations in $n+m$ variables. In such a system, only n variables can be endogenous. We must find values elsewhere for the remaining m exogenous variables. The software we use draws on the initial database for 1995 to derive initial values for the entire $n+m$ variables. Then, in effect, it transforms the equations so as to allow the selection of any n of these variables as endogenous. The remaining m variables are then either assumed to hold their database values or they can be subjected to exogenous shocks. This selection of variables as either endogenous or exogenous is what we refer to as the “closure”.

For example, in a “normal” simulation, such as when the technology shocks are imposed alone, the change in investment is endogenous and the investment premium factor $[(1+\pi)$ in equation 1] is exogenous. The technical changes are imposed as exogenous shocks to parameters that are already exogenous, namely to δ_s in equation (5) for the factor substitution case or δ_k in equation (12) for the capital-skill complementarity case. When we implement the US investment shock, however, we wish to represent a change in the locational preferences of savers. We do this by imposing a change in the investment premium of sufficient magnitude that it yields the requisite five per cent rise in US investment. And this is achieved by the construction of the closure. We simply make the change in investment in the US exogenous and impose a five per cent shock to it while making the US investment premium endogenous. These are the only exogenous shocks imposed yet a great deal depends on the choice of which remaining variables will be exogenous.

First, in the short run physical capital is industry specific and fixed in quantity in all regions. The return on installed capital is therefore endogenous and it differs by sector. Investment behaviour (equation 1) is then directed by the aggregate return on all of a region’s installed capital. Monetary policy is assumed to target the domestic CPI, P^C , in all regions except China, which maintains fixed nominal parity with the US dollar. This implies that nominal money supplies are endogenous in all regions and these are balanced by the exogeneity of P^C , which is held constant, in all regions except China and the nominal exchange rate, E , which is also held constant, in China. Monetary policy matters at this length of run because it sets the price level and hence, where the nominal wage is rigid, the

²³ See IMF (2000): Figure 1.2.

real wage of unskilled workers.²⁴ In the EU, labour market regulation is assumed to deliver a nominal wage that is fixed in the short run. In Canada and Australasia, and in China, some wage stickiness is assumed, such the nominal wage is assumed to adjust by half of any proportional change in the CPI ($\lambda=0.5$ in equation 2).²⁵ In these three regions the level of employment is therefore endogenous. On the other hand, in the US, Japan and other Asia, equation (2) is actually disabled to allow the nominal wage to adjust to clear the labour market and so keep employment fixed and the real wage of unskilled workers endogenous.

With this closure common to every case, four simulations are carried out. These are, first, assuming capital and skill are complements: (1) the imposition of a 3% capital enhancement in the US manufacturing and services sectors, and (2) the combination of this 3% capital enhancement with the observed 5% rise in US investment. Second, assuming capital and skill are substitutes, we simulate (1) the imposition of a 5% skill enhancement in the US manufacturing and services sectors, and (2) the combination of a 5% skill enhancement with the observed 5% rise in US investment. The results from these two experiments are displayed in Tables 6 and 7.

The effects of the US technology shocks alone:

Not surprisingly, irrespective of the representation of the base technology the technical change is positive from the point of view of the US. It pushes out the production possibility frontier and it raises real GDP, real consumption and real unit factor rewards.²⁶ Despite this common feature, the two technology characterisations yield quite different effects on the US economy. Consider first the case in which capital and skill are complementary. The rise in “effective” capital use reduces the real reward of “effective” capital in the US and raises the real reward of its complement, skill. Because capital demand is inelastic in the short run and responds negatively to a rise in the price of skill, the capital enhancement reduces the price of physical capital, or the real return to the fixed capital stock. This has a direct distributional effect, causing owners of physical capital to be reap a smaller return in the short run. More importantly, in our world of mobile savings, a fall in the return on installed capital in the US reduces its share of the world’s investment.

It is true that the expansion in US GDP and therefore in US savings tends to reduce the global interest rate, r^w , and hence the US interest rate.²⁷ But this fall is not sufficient to offset the more direct effect on US investment (via equation 1) of the proportionally larger decline in the return on US installed capital.²⁸ US investment therefore falls and investment in other regions rises. These indirect effects on the distribution of the world’s investment

²⁴ Because savings are fully mobile internationally, monetary policy in one region has no direct effect on the domestic interest rate while ever the interest premium remains exogenous. Recall from equation (1) that current investment is allocated to regions where the rate of return on installed capital is high. This rate of return and the regional interest rate, which is formed originally in the global market for loanable funds, will generally be different in short run departures from the steady state of the type simulated.

²⁵ Recall that the CPI is fixed by monetary targeting in all regions except China, so that in Canada and Australasia, variations in the nominal wage and real wages depend on deviations in the GDP deflator. Only in China are there substantial changes in both the nominal and real wages with the nominal wage change stemming from equation (2).

²⁶ The only exception to the general pattern of increased factor rewards is the real return to physical capital in the case where capital is enhanced. The reasons for this are discussed subsequently.

²⁷ Global savings is also increased in this case by economic expansion in the rest of the world as investment rises there.

²⁸ Our investors are myopic here in that the expected long run effect of the capital enhancement on the return to US installed capital is positive. This is made clear when the same shock is administered with the long run elasticities employed in Tyers and Yang (2000).

shift the US capital account towards deficit and the capital accounts of the other regions toward surplus. This causes a real depreciation in the US relative to its trading partners and, with the monetary policy settings assumed, a nominal depreciation as well. The consequence of this for the US is that relative price changes advantage tradeables sectors over services and so the expansion of the US economy is strongest in the manufacturing sector.

In the case where capital and skill are substitutes, the skill enhancement shock, while also yielding a substantial rise in US GDP, has the opposite consequence for the US share of the world's investment and hence for exchange rates. The rise in "effective" skill use in the US increases the real reward of its substitute, physical capital and so there is a rise in the real return to installed capital and therefore a rise in US investment. Although US savings rise, those in the rest of the world fall so that there is a net decline in global savings and interest rates rise, though not by enough to prevent the increase in US investment. The rise in US savings is also less than the change in US investment and so there is a boost to the US capital account surplus and a US real appreciation relative to the rest of the world. With the monetary policy settings assumed, this implies nominal appreciations against all regions except China, which targets its nominal rate against the US dollar. The effects of this on prices advantage the less-traded services sectors in the US most and the short run GDP expansion is larger than with the capital enhancement shock.

Turning to the rest of the world, the US shocks have indirect effects that are transmitted via two mechanisms. First, the technical change in the US shifts out its production possibility frontier by magnitudes that vary across commodities depending on their capital and skill intensities. This alters the terms of trade both in the US and abroad. Second, because the factor enhancement shocks change the return on installed capital in the US, they also change the global distribution of investment. This has two important consequences. Most directly, changes in investment affect aggregate demand. Less directly, changes in investment alter flows on the capital accounts of all countries and hence cause changes in real exchange rates. As it turns out, the dominant effect on overall economic activity is the change in investment. When that is positive in one of the other regions there is a partially offsetting real appreciation but there is also a terms of trade gain.

Thus, when capital and skill are complementary and capital is enhanced in the US, investment falls there but rises in other regions. The economies in the other regions therefore expand. This expansion is aided in the sticky wage regions by rises in producer prices associated with the real appreciation and hence falls in real wages and rises in employment. With the exception of China, central banks in each region target the respective CPIs. This allows GDP deflators to rise because imports (contained in the CPI) become cheaper relative to home goods. When capital and skill are substitutes and skill is enhanced in the US, on the other hand, the picture for other regions is reversed. Investment rises in the US and falls abroad. Other regions enjoy a real depreciation but it is insufficient to offset the investment change and so their economies contract. In economies with sticky nominal wages, this contraction is exacerbated by a fall in producer prices (and hence in the GDP deflator) and hence a rise in real wages and a fall in employment.²⁹

²⁹ This is exacerbated in China by a monetary policy that targets the US dollar rate. The real depreciation against the US requires a decline in the domestic price level and a rise in the real wage that is larger than in the other regions.

Adding the investment shock:

In the latter half of the 1990s a step-up of about five per cent was observed in US investment. On the face of it this is evidence in support of capital-skill substitution, since with that technology our simulations show a rise in US investment of three per cent. An alternative view is that the new-economy boom in the US attracted savers abroad who expected high returns in the long run from information technology investments and the adaptation of information technology for use in older industries. One way to represent this in our comparative static analysis is as a fall in the US risk premium. Indeed, we can even ask the model how much the US premium need change in order to attract the observed five per cent increase in investment. So this is what we do. We change the closure to make US investment exogenous and the US premium endogenous, leaving all other settings the same. For each technology specification we then impose an exogenous five per cent investment shock in the US.

Taken alone, the US investment shock is more clearly zero-sum than the technology shocks. It relocates investment away from the other regions and, the US real appreciation that follows notwithstanding, the other regional economies contract while the US economy expands. Within the US, the fall in the interest premium causes the home interest rate to fall relative to the global one and this suppresses US savings. The larger is the required reduction in the interest premium, therefore, the larger is the shift toward surplus on the US capital account and the larger is the US real appreciation relative to the other regions. And the larger the US real appreciation, the more the US expansion and the foreign contraction is centred on the services sectors.

Turning to our results, the US investment shock is combined with each technology shock in turn. Recall that, when capital and skill were considered substitutes and US capital was enhanced, the return on US installed capital fell as did US investment. Our requirement that the US premium adjust to allow a five per cent rise in US investment necessitates a substantial decline in the premium, as indicated in Table 6. As expected, this also yields a substantial US real appreciation relative to the rest of the world and hence a service sector led US expansion. In other regions, the loss of investment causes a general contraction that is largest in their services sectors while their tradeable goods sectors expand.³⁰

When we characterised capital and skill as substitutes and imposed a US skill enhancement, recall that the return on US installed capital rose and global investment was redistributed in favour of the US, which then experienced a real appreciation relative to the other regions. US investment rose three per cent. The decline in the US interest premium needed to push this up to five per cent is therefore smaller than in the capital-skill complementarity case. This is made clear in Table 7. Although the incremental effects of the investment shock are therefore smaller in this case, the net effects of the technology and investment shocks on the regional distribution of global output and real consumption are similar to those emerging when capital and skill are considered complements. This is not surprising since the US investment shock has the same magnitude in both cases. Yet the sectoral and distributional effects within regions differ substantially between the two technology characterisations. When capital and skill are complements, the skill premium is raised more in the US and it falls by more in the other regions. Since a larger real

³⁰ The case of China differs again here. Its real depreciation, combined with its exchange rate targeting, requires a fall in home prices and hence a rise in its real wage. This causes a substantial loss of employment. For more on the consequences of China's monetary policy, see Yang and Tyers (2000).

appreciation occurs in this case, some US tradeable goods sectors contract and land and natural resource rents actually decline.

5. Conclusion

In an earlier study of technical changes affecting the global economy in the period 1975-95, Tyers and Yang (2000) found two alternative technology characterisations to offer equivalent explanations. Technologies could either be characterised as exhibiting capital-skill complementarity, in which case the technical change would have been capital enhancement, or capital-skill substitution, in which case the technical change would have been skill enhancement. For our long run analysis it did not seem to matter which of these characterisations was adopted. This paper examines one reason why it does matter. The two characterisations have different implications in the short run when other properties of the global economy are changing through time. Two key properties of the global economy appear to have been changing in during the last two decades. First, international capital mobility has increased, so that the global distribution of the world's investment is now more sensitive to regional differences in interest rates and returns on installed capital than it was in the 1970s. And second, there is evidence that the shocks associated with the adoption of information technology grew larger during the period.

To examine the implications of the two technology characterisations in the “new economy” era of the late 1990s, we construct a short run macroeconomic model and embed the two technology characterisations in it. The model is then subjected to technology and investment shocks. The results indicate, first, that the two technology characterisations are not equivalent in short run analysis when capital is internationally mobile, mainly because technology shocks have different implications for the return to installed capital and hence the global distribution of investment. Second, when capital and skill are complementary, consistent with key empirical studies of skilled labour demand (Hamermesh 1993, and Krusell et al. 1997), the technology shock alone does not explain the flood of savings into the US that was observed in the “new economy” era. For this, expectations of increased future returns on US investment are required.

Third, when the technology shock is combined with a shock to the US risk premium sufficient to deliver the observed rise in US investment, the US suffers a substantial real appreciation against the other regions that redistributes resources away from US tradeable goods industries and toward services. Although the skill premium rises, land and natural resource rents decline. And, finally, in the other regions, the primary effect of the combined new economy shocks is to redistribute investment away from them and into the US. This causes contractions in their less-traded services sectors while their tradeable goods sectors tend to expand.

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Table 1: Model structure

Regions	Share of 1995 world GDP ^f
1. Rapidly growing Asia ^a	5.1
2. Japan	18.0
3. China ^b	2.5
4. European Union ^c	29.0
5. United States	25.2
6. Canada and Australasia	3.5
7. Rest of world	16.8
Primary factors	
1. Agricultural land	
2. Natural resources	
3. Skill	
4. Labour	
5. Physical capital	
Sectors ^e	
1. All agriculture	
2. Mining and energy (coal, oil, gas and other minerals)	
3. Skill-intensive manufacturing (petroleum, paper, chemicals, processed minerals, metals, motor vehicles and other transport equipment, electronic equipment and other machinery and equipment)	
4. Labour-intensive manufacturing (textiles, apparel, leather and wood products, metal products, other manufactures)	
5. Skill-intensive services (electricity, gas, water, financial services and public administration)	
6. Labour-intensive services (construction, retail and wholesale trade, dwellings)	

a Korea (Rep.), Indonesia, Philippines, Malaysia, Singapore, Thailand, Vietnam, Hong Kong and Taiwan.

b China excludes Hong Kong and Taiwan.

c The European Union of 15.

d These are aggregates of the 50 sector GTAP Version 4 database. See McDougall et al. (1998a).

e Share of 1995 GDP in US\$ measured at market prices and exchange rates.

Table 2: Short Run Elasticities of substitution in final and intermediate product demand^a

Sector	In product demand, between domestic and imported	In import demand, between regions of origin
Agriculture	1.8	3.4
Mining	2.0	4.1
Manufacturing: labour intensive	2.7	5.8
skill intensive	1.6	3.3
Services: labour intensive	0.9	1.9
skill intensive	1.0	1.9

a These are group-specific weighted averages across the 50 industries defined in the database. The CDE parameters governing substitution in final demand are discussed in McDougall et al. (1998b).
Source: GTAP Database Version 4.1. See McDougall et al. (1998a).

Table 3: Branch elasticities of substitution in the case where all factors are substitutes

Sector	In production between intermediates and primary factors, σ_Y	In value added, between labour- skill, capital, resources and land, σ_{VA}	Between labour and skill, σ_{VLS}
Agriculture	0.0	0.1	0.4
Mining	0.0	0.1	0.4
Manufacturing: labour intensive	0.0	0.6	1.5
skill intensive	0.0	0.6	1.5
Services: labour intensive	0.0	0.8	1.8
skill intensive	0.0	0.6	1.5

Source: The value added branch elasticities are larger than the standard GTAP factor substitution elasticities, to reflect the long run as explained in the text. See Table 19.2 of McDougall et al. (1998b).

Table 4: Branch elasticities of substitution in the case where capital and skill are complements

Sector	In production between intermediates and primary factors, σ_Y	In value added, between capital- labour-skill, resources and land, σ_{VA}	Between capital- skill and labour, σ_{VKL}	Between capital and skill, σ_{VKS}
Agriculture	0.0	0.1	0.3	0.2
Mining	0.0	0.1	0.3	0.2
Manufacturing: labour intensive	0.0	0.6	1.4	0.4
skill intensive	0.0	0.6	1.6	0.4
Services: labour intensive	0.0	0.8	2.0	0.5
skill intensive	0.0	0.6	1.6	0.4

Source: The value added branch elasticities are larger than the standard GTAP factor substitution elasticities, to reflect the long run as explained in the text. See Table 19.2 of McDougall et al. (1998b).

Table 5: Implied Short Run Elasticities of Primary Factor Demand in the United States^a

Sector:	Own price			Cross price					
	Labour, L	Skill, S	Capital, K	K-L	L-K	K-S	S-K	S-L	L-S
<i>All factors substitutes</i>									
Agriculture	-0.09	-0.38	-0.06	0.03	0.04	0.00	0.04	0.31	0.02
Mining	-0.17	-0.30	-0.06	0.02	0.04	0.01	0.04	0.23	0.10
Labour intensive mfg	-0.54	-1.20	-0.36	0.27	0.24	0.09	0.24	0.96	0.30
Skill-intensive mfg	-0.75	-0.98	-0.37	0.22	0.23	0.15	0.23	0.75	0.52
Labour intensive services	-0.65	-1.48	-0.47	0.37	0.33	0.10	0.33	1.15	0.32
Skill intensive services	-0.90	-0.77	-0.43	0.20	0.17	0.24	0.17	0.60	0.73
<i>Capital and skill complements</i>									
Agriculture	-0.19	-0.10	-0.16	0.11	0.13	0.00	-0.06	0.11	0.01
Mining	-0.24	-0.10	-0.12	0.06	0.15	0.00	-0.02	0.06	0.03
Labour intensive mfg	-0.66	-0.40	-0.49	0.54	0.49	-0.05	-0.14	0.54	0.17
Skill-intensive mfg	-0.76	-0.36	-0.38	0.44	0.46	-0.06	-0.08	0.44	0.30
Labour intensive services	-0.75	-0.46	-0.59	0.65	0.58	-0.06	-0.19	0.65	0.18
Skill intensive services	-0.77	-0.35	-0.33	0.38	0.32	-0.05	-0.03	0.38	0.45

^a These are conditional elasticities for the U.S. Those for other regions will differ as factor shares in total cost differ.

Source: Branch elasticities in Tables 3 and 4 and factor and input shares for the United States in 1995, drawn from the GTAP database (McDougall et al. 1998a).

Change in:	USA	EU	Canada Au-NZ	Japan	China	Other E. Asia
Nominal exchange rate(US\$/●), E_i (%)	0.0	-2.9	-1.6	-3.0	0.0*	-2.1
Domestic CPI, P^C (%)	0.0*	0.0*	0.0*	0.0*	-2.2	0.0*
Domestic GDP deflator, P^Y (%)	0.2	-0.2	0.0	-0.1	-2.1	-0.1
Nominal money supply, M_S (%)	1.0	-0.3	-0.1	-0.2	-2.4	-0.1
Real effective exchange rate ^b , e_i^R (%)	2.7	-1.5	-0.5	-1.4	-0.1	-0.2
Real exchange rate against USA, e_{ij}^R (%)	0.0	-3.3	-1.8	-3.3	-2.4	-2.4
Terms of trade ^c (%)	2.0	-0.5	0.1	-1.4	0.0	-0.1
Global interest rate, r^w	0.6	0.6	0.6	0.6	0.6	0.6
Investment premium factor, $(1+\pi)$ (%)	-1.4	0.0*	0.0*	0.0*	0.0*	0.0*
Home interest rate, r (%)	-0.8	0.6	0.6	0.6	0.6	0.6
Return on installed capital ^d , r^c (%)	2.9	-0.8	-0.1	-0.1	-0.8	-0.1
Real domestic investment, I (%)	5.0*	-2.3	-1.0	-1.0	-1.1	-0.6
Real consumption, C (%)	1.7	-0.4	0.0	-0.1	-0.4	-0.1
Balance of trade, $X-M$ (US\$b)	-53.2	31.4	1.5	10.6	0.8	3.5
<i>Real gross sectoral output (%)</i>						
Agriculture	-0.1	0.1	0.0	0.1	-0.2	0.0
Mining	0.1	0.2	0.1	0.5	0.1	0.2
Manufacturing: labour-intensive	0.4	0.0	0.0	0.1	-0.2	0.1
skill-intensive	0.4	0.2	0.1	0.3	-0.3	0.1
Services: labour-intensive	1.7	-0.4	-0.2	-0.2	-0.6	-0.1
skill-intensive	1.5	-0.1	-0.1	0.0	-0.4	0.0
Real GDP, Y (%)	1.3	-0.2	-0.1	0.0	-0.4	0.0
<i>Unskilled wage and employment</i>						
Nominal (unskilled) wage, W (%):	0.6	0.0*	0.0*	-0.3	-1.1*	-0.3
Production real wage, $w=W/P^Y$ (%):	0.4	0.2	0.0	-0.2	1.1	-0.2
Employment, L^D (%)	0.0*	-0.2	-0.1	0.0*	-0.8	0.0*
<i>Unit factor rewards CPI deflated (%)</i>						
Labour	0.6	0.0	0.0	-0.3	1.1	-0.3
Skill	2.0	-0.2	-0.1	-0.3	0.1	-0.3
Capital	2.1	-0.4	0.0	0.0	-0.7	-0.1
Land	-2.0	1.8	-0.3	2.7	-2.4	1.0
Natural resources	3.0	6.1	4.8	4.1	2.2	3.3

- a All variables shown are endogenous, except for the CPI change in all regions but China, the US-China nominal exchange rate, the level of real investment in the US, the investment premia on interest rates in the other regions, the nominal wage of low skill workers in the EU, CANZ and China and the levels of employment in the US, Japan and RG Asia. The exogenous changes are marked with an asterisk (*).
- b Change in the trade weighted average value of $e_{ij}^R = (E_i/E_j) P_i^Y/P_j^Y$ over regions j .
- c Change in the value of exports at endogenous prices, weighted by fixed 1995 (base period) export volumes, divided by the value of imports, weighted by fixed 1995 import volumes.
- d Per cent change in payments to capital less the per cent change in the capital goods price index.