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FOREIGN EXCHANGE:
DUTCH DISEASE DYNAMICS**

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ABSTRACT

Absorbing a windfall of foreign exchange: Dutch disease dynamics*

The response of an economy to a windfall of foreign exchange (be it aid or natural resource revenues) is often constrained by absorptive capacity. We provide a micro-founded analysis of absorption constraints, based on the idea that expanding the economy's capital stock (in aggregate or sectorally) requires non-traded inputs, the supply of which is constrained by the initial capital stock. Given this constraint, the economy will manifest 'Dutch disease' symptoms, although many of them are temporary. On impact there is sharp appreciation of the real exchange rate, which will then depreciate back to its equilibrium level. In contrast to the permanent income hypothesis, real consumption jumps part of the way to its new long-run level, and then continues to rise. Depending on the capital-intensity of the investments needed for the adjustment, the economy may run a current account deficit or surplus in early years.

JEL Classification: O11, O16, E21, E22, F10, F35, H63 and Q33

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1. Introduction

How does an economy respond to a foreign exchange windfall such as that associated with discovery of a natural resource, a commodity boom, or an increase in aid or remittances? At the simplest level agents (private and public) in the economy have three options. One is to invest abroad, insulating the economy from the foreign exchange windfall but pushing consumption benefits into the future. A second is to invest domestically, so the windfall is spent on building up productive capacity to supply future consumption. And the third is to consume immediately, this raising demand for both domestic output and imports. The balance between these options is shaped by numerous factors (Collier et al., 2010), including initial levels of income and capital scarcity (van der Ploeg and Venables, 2010); expectations about the sustainability of the windfall (Gelb and Grasmann, 2008); and the political economy of alternative choices (Collier and Gunning, 2005). This paper focuses on a further issue, which is the ability of the economy to absorb additional spending. Can increases in domestic consumption and investment be undertaken rapidly, or do they run into supply constraints and bottlenecks in the domestic economy?

The development literature makes frequent use of the term ‘absorptive capacity’, particularly in the context of international aid, although generally without the basis of a formal model. For example, Bourguignon and Sunderg (2006) argue that absorptive capacity is constrained by three factors.¹ Scarcity of skilled workers, physical capital, and infrastructure; relative price effects including increases in the price of non-tradables which reduce the real value of aid and harm the competitiveness of the economy; and institutional constraints in a country’s budget management, accounting and procurement processes. We provide a formal analysis in which absorptive capacity is constrained by slow adjustment of capital of various sorts, and we draw out the implications for relative prices, income and expenditures. Although our context is adjustment to a foreign exchange windfall, we think the general approach developed here can be applied to adjustment to a wider range of shocks.

The central issue, important in many contexts, is that the economy faces adjustment to a new long-run structure, such as a larger non-traded goods sector. The reference point is an economy which can jump instantaneously to this new structure. This is possible if all sorts of capital – skills, capital equipment, and infrastructure – can be redeployed or bought and sold on world markets, so that bottlenecks are not encountered and relative prices need not

¹ See also de Renzio (2005) and Mavrotas (2007). The industrial organisation literature uses the term absorptive capacity quite differently, to mean a firm’s ability to absorb new ideas or technologies.

change. We argue that the heart of the absorption problem is that this is not possible, for two reasons. First, much physical capital is sunk so cannot be costlessly redeployed, and second, some sorts of capital are non-traded and cannot be acquired on world markets. This latter point is crucial although country specific. Some resource rich countries (some of the Gulf States) have made essentially all capital tradable; human capital is imported by immigration of skilled workers, and infrastructure is imported by immigration of construction workers. Some Chinese investments in Africa take a similar form, using Chinese workers and equipment to construct infrastructure as payment for natural resources. But in many other countries this option is politically infeasible, so the essential problem is that creating new capital requires *non-traded* capital. This may be physical capital, or may be human capital; it takes teachers to produce teachers. It is this shortage of ‘home-grown’ capital that we believe is the quintessential determinant of absorptive capacity.

Whilst our approach to absorption is applicable to structural change in various contexts, our analysis surrounds adjustment to a foreign exchange windfall and consequent ‘Dutch disease’ issues that may arise. The existing literature on the Dutch disease has three main strands. The first is to do with short run macro-economic adjustment and the role of monetary and exchange rate policy (e.g. Eastwood and Venables 1982, Neary and Purvis, 1982; Gupta and Heller 2002). The second concerns the long-run structural change that arises as spending from the windfall increases non-traded goods production and crowds out domestic production of traded goods (e.g., Corden and Neary, 1982). The third adds market failures to this, suggesting that there may be learning economies or other external benefits in the traded goods sector, so a reduction in its size is a potential source of real income loss (van Wijnbergen, 1984; Sachs and Warner, 1997; Torvik, 2001). The gap that the present paper seeks to fill is to do with the short- to medium-run supply response of the economy to a windfall. What determines the rate at which the economy adjusts to its new structure? What are the implications for the mix of consumption, domestic investment, and foreign investment of windfall revenues? How might an economy increase the speed at which it absorbs the windfall?

The next section of the paper sets out a rudimentary model that introduces some of the building blocks we use, provides some comparative statics and is also a useful device to connect the present paper to parts of the existing literature. Section 3 turns to the intertemporal adjustment issues of saving and investment which are central to our approach. Consumers and firms make intertemporally optimising decisions and are able to borrow and lend at the world interest rate. But although financial capital is internationally mobile,

physical capital equipment is not. Production of capital equipment requires some non-tradable inputs, so must be (partly) ‘home-grown’. Even though the economy has perfect access to international capital markets the requirement that it accumulates capital goods with a domestic component means that it cannot jump instantaneously to a new steady state. Instead there is an adjustment path along which relative prices are changing and economic agents vary consumption and investment in response to the path of prices. Section 4 analyses this response, and section 5 draws out policy implications.

2. Comparative statics of the Dutch disease

The theory of the Dutch disease suggests that the non-resource traded goods sector of the economy contracts in response to a foreign exchange windfall in order to accommodate additional spending on non-tradables. Early evidence for a shrinking manufacturing sector in response to terms of trade shocks and real appreciation has been mixed (e.g. Sala-i-Martin and Subramanian 2003), but more recent evidence points to the presence of this structural change. A recent study using disaggregated sectoral data for manufacturing finds that a 10% increase in the size of the windfall is on average associated with a 3.4% fall in value added across manufacturing, but less so in countries that have restrictions on capital flows and for sectors that are more capital intensive (Ismail, 2010). Using as counterfactual the Chenery-Syrquin (1975) norm for the size of tradables, countries in which the resource sector accounts for more than 30% of GDP have a tradables sector 15 percentage points lower than the norm (Brahmbhatt, et al., 2010). Harding and Venables (2010) look at the trade side, breaking the effects into changes in non-resource exports and imports. They find that the response to an increase in resource exports is a fall in non-resource exports by 35-70 percent of the increase, while non-resource imports rise by 0-35 percent of the increase. Furthermore, about 30 percent of the windfall is saved.² The macroeconomic and sectoral evidence thus seems to offer support for Dutch disease effects.

Given these facts, we start by laying out a comparative static model which serves several purposes. One is to introduce parts of the more complex dynamic model that follows, and the other is to provide a framework for a brief review of the existing analytical literature on the Dutch disease. We stress that the model of this section provides the framework but the

² These findings hold in pure cross-sections of countries (averages across one, two, three or four decades), in pooled panels of countries, and in panel estimations including dynamics and country fixed effects.

full behavioural model which endogenises the responses of households, firms, and hence capital stocks, follows in section 3.

The model has two sectors, tradable and non-tradable, each with a sector-specific capital stock, K^T, K^N . We look in this section at cases where these capital stocks are fixed – the ‘short run’ – and where they fully adjust, the ‘long run’. Firms are perfectly competitive and use labour and capital to produce output under constant returns to scale. The technology of each sector can be represented by unit cost functions, $c^N(r^N, w)$, $c^T(r^T, w)$ where w is the wage, common to both sectors, and r^N, r^T are the returns to sector specific capital (variables are denoted by italics and functions by Roman letters). Equality of unit cost to prices p^N, p^T , means that

$$c^N(r^N, w) = p^N, \quad c^T(r^T, w) = p^T. \quad (1)$$

Notice that these can be inverted to define rate of return functions,

$$r^N = r^N(w, p^N) = (p^N w^{-(1-\alpha^N)})^{1/\alpha^N}, \quad r^T = r^T(w, p^T) = (p^T w^{-(1-\alpha^T)})^{1/\alpha^T} \quad (2)$$

where the second equations are the Cobb-Douglas specifications, with capital share in each sector α^N, α^T .³ Factor market clearing, for each of the specific factors and for labour, gives

$$K^N = c_r^N(r^N, w)x^N = x^N / r_p^N(w, p^N) = \alpha^N p^N x^N / r^N, \quad (3)$$

$$K^T = c_r^T(r^T, w)x^T = x^T / r_p^T(w, p^T) = \alpha^T p^T x^T / r^T, \quad (4)$$

$$L = c_w^T(r^T, w)x^T + c_w^N(r^N, w)x^N = -[K^N r_w^N(p^N, w) + K^T r_w^T(p^T, w)] \quad (5)$$

$$= [(1-\alpha^N)p^N x^N + (1-\alpha^T)p^T x^T] / w,$$

where L is the labour force, and x^T, x^N are output levels. In each of these expressions we have the representation from the cost function (Shephard’s lemma), from the rate of return function (Hotelling’s lemma), and from the specific Cobb-Douglas form (the value of labour demand is a constant share $1-\alpha^N, 1-\alpha^T$ of the value of output).

³ Rate of return functions are restricted profit functions expressed per unit of the single fixed factor (capital). For properties see Varian (1992).

A windfall of foreign exchange will increase spending by domestic households. Some of this spending will fall on tradables and increase in imports (or reduce exports); some will fall on non-tradables, x^N , this causing structural change in the economy and the ‘Dutch disease’. What are the short and long run effects of an increase in x^N ? Answers are summarised in table 1.

Suppose first that in the long run K^T , K^N are both variable and that capital can be obtained from world markets at fixed rental rate r^* , so $r^T = r^*$, $r^N = r^*$. In that case, the wage rate and price of non-tradables are pinned down by the exogenous world rental rate of capital, r^* and world price of tradables, p^T , as is apparent from columns 2 and 3 of the first row of table 1.⁴ The domestic supply curve of non-tradables is horizontal so an increase in x^N has no price effects, and is associated with a relatively large quantity effect.

Table 1: Short- and long-run comparative statics of the Dutch disease

K^T, K^N flexible	$r^* = r^T(w, p^T)$	$r^* = r^N(w, p^N)$	$\frac{dw}{dx^N} = 0, \frac{dp^N}{dx^N} = 0$
K^N fixed	$r^* = r^T(w, p^T)$	$K^N = \frac{x^N}{r_p^N(w, p^N)}$	$\frac{dw}{dx^N} = 0, \frac{dp^N}{dx^N} > 0, \frac{dr^N}{dx^N} > 0$
K^T fixed	$L = -K^T r_w^T(p^T, w) - x^N \frac{r_w^N(p^N, w)}{r_p^N(p^N, w)}$	$r^* = r^N(w, p^N)$	$\frac{dw}{dx^N} > 0, \frac{dp^N}{dx^N} > 0, \frac{dr^T}{dx^N} < 0$
K^T, K^N fixed	$L = -K^N r_w^N(p^N, w) - K^T r_w^T(p^T, w)$	$K^N = \frac{x^N}{r_p^N(w, p^N)}$	$\frac{dw}{dx^N} > 0, \frac{dp^N}{dx^N} > 0$ $\frac{dr^N}{dx^N} > 0, \frac{dr^T}{dx^N} < 0$

What if K^T is variable but K^N is fixed (e.g. if the non-tradable sector used a specific factor such as land)? Since the tradeable sector has fixed price of capital and of output the level of the wage is also fixed, as is clear from the rate of return function (second row, second column of table 1). The supply curve of the non-tradable is however constrained by a given

⁴ Factor price invariance with respect to demand and capital stocks holds because of constant returns and the fact that as many things are traded as non-traded; there are two non-traded goods (N and labour) and two traded (T and financial capital which sets factor price r^*). This also holds in the dynamic model put forward in the appendix of Sachs and Warner (1997), where all the adjustment comes from the capital stock while the real exchange rate, i.e. the price of non-tradables is pinned down by the world interest rate.

quantity of K^N (second row, third column), so is upwards sloping and an increase in p^N is required, this increasing r^N and reducing the capital labour ratio in the sector.

If K^N is variable but K^T is fixed then the constraint faced when expanding x^N is not the supply of capital, but the supply of labour. Analytically, responses of p^N and w come from the two equations in the third row of table 1, labour market clearing and the non-tradeable sector's rate of return function. The wage must rise in order to induce the traded good sector to release labour, and accompanying this there must be an increase in p^N if the tradable sector is to continue to break even.

Finally, the most constrained case is the short-run in which both K^N and K^T are assumed to be constant, as discussed in the classic analysis of the Dutch disease by Corden and Neary (1982). Response to an increase in demand for non-tradables then comes from the two equations in the bottom row of table 1, and once again requires both an increase in the wage to release labour from the tradable sector, and an increase in the price of non-tradables. At this point it will be the case that $r^N > r^*$ and $r^T < r^*$ this indicating the direction of long-run changes in capital stocks in each sector.

The cases captured here either have diminishing returns (the short run) or constant returns (the long run). A small modification of our comparative static setting allows us to capture increasing returns by supposing that unit costs in the tradable sector are a decreasing function of the capital stock in the sector so, for example, $c^T(r^T, w)(K^T)^{-\mu} = p^T$, $\mu > 0$. A reduction in K^T is then like a reduction in the price of tradables, and the analysis given above can be reworked correspondingly. Much of the literature captures increasing returns to tradables through a dynamic story of learning by doing (van Wijnbergen 1984, Krugman 1987, Sachs and Warner, 1997)^{5 6}. This can be done within our framework by supposing that unit costs in the tradable sector are $c^T(r^T, w)/\Theta = p^T$ with productivity growth in this sector given by $\dot{\Theta}/\Theta = \mu_1 K^T + \mu_2 c_w^T x^T - \mu_0$, $\mu_0, \mu_1, \mu_2 > 0$, thereby moving from a model of exogenous growth to one of endogenous growth. A temporary windfall then depresses the growth rate of

⁵ The hypothesis that resource windfalls reduce growth (via a shrinking manufacturing sector and loss of learning by doing) underlies the empirical resource curse literature, which finds that resource-rich countries with relatively poor institutions, trade restrictions and little financial development suffer worse growth prospects even after controlling for determinants such as initial income per capita, saving, education, openness, institutional quality and population growth (Sachs and Warner, 1997; van der Ploeg, 2010).

⁶ Torvik (2001) generalises these arguments by allowing learning by doing to be generated in either sector and to spill-over between sectors; a windfall of foreign exchange only has an adverse effect if learning by doing effects are more powerful in the traded sector than in the non-traded sector. Matsen and Torvik (2005) study the optimal trade-off between the benefits of consuming the windfall and induced loss of learning by doing.

the economy as capital and labour are shifted from the traded to the non-tradable goods sector, leading to a permanent loss in productivity and output.

This sketches the responses of the economy under different assumptions about the adjustment of capital stocks in each sector. In the analysis that follows we endogenise this adjustment, incorporating the fact that home-grown capital has to be accumulated. Investors and consumers are intertemporally optimising, so slow adjustment of the supply side of the economy is mirrored by slow adjustment of consumption. We trace out the extent to which a windfall is consumed, held in foreign assets, and invested in the domestic economy. As our focus is on absorption of the windfall and the dynamic adjustment path it supports, we assume that there are no market imperfections, abstracting from increasing returns to scale and learning by doing.

3. The dynamic model

Equations (1) – (5) of the preceding section describe the technology and give factor market clearing conditions. We retain these equations, and equations (6)-(11) below will add a full model of the investment behaviour of firms and of intertemporal choice by consumers.

The first ingredient is investment in each sector, I^N, I^T , and associated capital stock dynamics,

$$\dot{K}^N = I^N - \delta^N K^N, \quad \dot{K}^T = I^T - \delta^T K^T, \quad (6)$$

where δ^J is the depreciation rate in each sector, $J = T, N$. Investment decisions are taken to maximise the present value of profits net of capital costs. We assume perfect access to international capital markets, so agents can borrow or lend at world rate of interest r^* . The capital goods purchased for investment are a composite of tradable and non-tradable goods. The unit cost functions for each sector's capital goods are therefore $b^N = b^N(p^T, p^N)$ and $b^T = b^T(p^T, p^N)$. The fact that production of capital goods requires non-traded goods is at the heart of our modelling of absorptive capacity, as discussed in the introduction. It captures the idea that the capital stock is partly imported equipment and partly locally produced structures or skills. The present value of a unit of investment in sector J , yielding rate of return $r^J(p^J, w)$, costing $b^J(p^T, p^N)$ and undertaken at time t is then

$$PV_t^J = \int_t^\infty r^J(p^J, w) e^{(r^* + \delta^J)(t-z)} dz - b^J(p^T, p^N), \quad J = T, N. \quad (7)$$

Equilibrium present values PV_t^J are zero if investment is being undertaken and negative if not.

The representative consumer can borrow or lend at rate of interest r^* so has intertemporal budget constraint

$$\int_0^{\infty} [p^T x^T + p^N x^N - u E(p^T, p^N) - b^N(p^T, p^N) I^N - b^T(p^T, p^N) I^T] e^{-r^* t} dt \leq A_0 \quad (8)$$

Income is the value of output of tradables and non-tradables, x^T, x^N , and expenditure goes on consumption and investment. The final two terms in square brackets are the cost of investment, and the preceding term is the cost of consumption where u is utility or real consumption and the consumer has homothetic preferences with unit expenditure function (price index) $E = E(p^T, p^N)$. A_0 denotes the initial stock of foreign assets. In the absence of the windfall we set this at zero. The windfall takes the form of a flow of income $v(t)$ with present value at date 0 of $V_0 = \int_0^{\infty} v(z) e^{-r^* z} dz$. Since borrowing and lending at world interest rate r^* is possible, the exact timing of flows of windfall revenue is immaterial, and their present value is all that matters. The windfall is therefore represented as an increase in foreign assets by amount V_0 announced at date $t = 0$, so $A_0 = V_0$. The evolution of foreign assets is given by the flow budget constraint,

$$\dot{A} = r^* A + \{v - r^* V_0\} + p^T x^T + p^N x^N - u E(p^T, p^N) - b^N(p^T, p^N) I^N - b^T(p^T, p^N) I^T, \quad (9)$$

with $A_0 = V_0$. Notice that $r^* V_0$ is the annuity value or permanent income equivalent of the windfall, and in examples that follow we will assume that $v = r^* V_0$ at all dates.

The consumer has intertemporal objective $\int_0^{\infty} \frac{u^{1-\sigma}}{1-1/\sigma} \exp(-\rho t) dt$ where σ is the intertemporal elasticity of substitution and ρ is the rate of time preference, assumed to equal the world rate of interest r^* . Intertemporal choice therefore means that

$$u^{-1/\sigma} = \lambda E(p^T, p^N), \quad (10)$$

where λ is the marginal utility of wealth which is constant through time, except at the date the windfall is announced.⁷ The time derivative of this first-order condition is the Ramsey rule,

⁷ Equation (10) is the first-order condition for maximisation of the objective subject to budget constraint (8).

saying that instantaneous real consumption, u , increases (decreases) over time if the cost of living falls (rises), and more so if the elasticity of inter-temporal substitution σ is large.

The final equilibrium condition is the equality of supply to demand for non-traded goods, where demand comes both from final consumption and investment,

$$x^N = u E_{p^N}(p^T, p^N) + I^N b_{p^N}^N(p^T, p^N) + I^T b_{p^N}^T(p^T, p^N). \quad (11)$$

This equation can be thought of as determining the price of non-tradables, p^N . Notice that the dynamic equilibrium characterised by these equations has no market imperfections, so the equilibrium is efficient.

3.1. Reduced form

To analyse the system we make a few substitutions. Tradable goods are numeraire, so $p^T = 1$, the price of non-traded goods (or real exchange rate) is denoted $p \equiv p^N/p^T$, and we rewrite cost and expenditure functions accordingly. For a given value of the marginal utility of wealth, λ , putting equations (3), (6) and (10) into the non-traded goods market clearing condition (11) gives

$$K^N r_p^N(p, w) - [\lambda E(p)]^{-\sigma} E_p(p) = [\dot{K}^N + \delta^N K^N] b_p^N(p) + [\dot{K}^T + \delta^T K^T] b_p^T(p). \quad (12)$$

The left-hand side is the supply of non-traded goods available for investment, and is increasing in the price p ; the right-hand side is demand for these goods in investment. Investment behaviour implies zero present value when investment is being undertaken. Thus, differentiating (7) with respect to time gives investment arbitrage conditions,⁸

$$\dot{p} b_p^N(p) = (r^* + \delta) b^N(p) - r^N(p, w) \quad \text{if } I^N > 0, \quad (13)$$

$$\dot{p} b_p^T(p) = (r^* + \delta) b^T(p) - r^T(w) \quad \text{if } I^T > 0. \quad (14)$$

If investment is positive in each sector then the division of investment between sectors must be such as to make both equations hold. It may be the case that investment is occurring in just one sector, in which case it is that with the higher return. The final equilibrium condition is labour market clearing, equation (5), which we reproduce as

⁸ These generalise the conditions $r^* = r^j(p, w)$ of section 2, adding depreciation and endogenous price of capital equipment.

$$L + K^N r_w^N(p, w) + K^T r_w^T(w) = 0. \quad (15)$$

For a given value of λ equations (12) - (15) give the behaviour of K^T , K^N , p and w .

We analyse the effects of a windfall, V_0 , which enters equations (12) – (15) by reducing the value of the marginal utility of wealth. A resource windfall thus corresponds to an unanticipated and permanent fall in λ . We use Δ to denote the difference between the new and the initial steady state, and so take $\Delta\lambda < 0$ as the exogenous shift, showing below how this is linked to the size of the windfall V_0 . Initial values of K^T and K^N are fixed, but p and w can jump in order to put the economy on a path to the new long-run equilibrium.

3.2. Steady state

Before analysing the dynamics we need to establish the effects of the windfall on long-run stationary values of endogenous variables. This comes from solving equations (12)-(15) for the stationary equilibrium values of K^T , K^N , p and w as a function of the marginal utility of wealth, λ . Looking first at the price side, equations (13) and (14) mean that long-run p and w are independent of λ and we denote these long-run values \bar{p} , \bar{w} . This is a consequence of constant returns to scale, and is similar to what we saw in section 2, although the cost of capital is no longer just r^* but instead $(r^* + \delta)b^J(p)$, $J = T, N$. Notice that long-run wages and prices also determine the long-run prices of capital goods, $b^N(\bar{p})$ and $b^T(\bar{p})$, and hence techniques of production. It also implies that the long-run increase in utility is, from (10), $\Delta u = [(\lambda_0 + \Delta\lambda)E(\bar{p})]^{-\sigma} - [\lambda_0 E(\bar{p})]^{-\sigma} > 0$. For small values of $\Delta\lambda$ this becomes $\Delta u / u_0 = -\sigma\Delta\lambda / \lambda_0$, indicating that a higher elasticity of intertemporal substitution means that a given fall in the marginal utility of wealth induces a larger increase in utility (real consumption).

Changes in steady-state capital stocks ΔK^N , ΔK^T come from equations (12) and (15). Explicit expressions are given in appendix 1, and we simply note that, given an increase in demand for non-tradables, $E_p(\bar{p})\Delta u$, we have $\Delta K^N > 0$ and $\Delta K^T < 0$ indicating the usual ‘Dutch disease’ response of an increase in capital stock in the non-traded sector and fall in the traded sector. Whether the aggregate capital stock of the economy, $\Delta K^N + \Delta K^T$, expands or contracts in response to $\Delta u > 0$ depends on whether non-tradables are more or less capital intensive than tradables.

How are changes $\Delta\lambda$, Δu , ΔK^N and ΔK^T linked to the size of the windfall, V_0 ? The long-run change Δu must be supported by an additional income flow of $E(\bar{p})\Delta u$. The wage is unchanged, so this must be provided by income from assets. Changes in assets (both physical and foreign) must therefore satisfy

$$r^* [V_0 + \Delta A + b^N(\bar{p})\Delta K^N + b^T(\bar{p})\Delta K^T] = E(\bar{p})\Delta u. \quad (16)$$

Formal derivation of this comes from the budget constraint (9), holding prices constant and using (13), (15) and $I^J = \delta K^J$. One further equation is needed, and this is straightforward in the case where the economy can jump to the new steady state. If we suppose that the economy *can* buy and sell its physical capital stock instantaneously on world markets then the value of these purchases/ sales mean that there is an instantaneous change in net foreign assets, ΔA , satisfying $\Delta A + b^N(\bar{p})\Delta K^N + b^T(\bar{p})\Delta K^T = 0$. Using this in (16) gives $r^*V_0 = E(\bar{p})\Delta u$. This is simply the permanent income hypothesis, saying that the permanent increase in real consumption $E(\bar{p})\Delta u$ is equal to the permanent income flow from the windfall, r^*V_0 . However, if capital goods cannot be fully traded internationally this instantaneous jump is not possible. Instead, the long-run value ΔA has to be derived by integrating along the path of foreign asset accumulation, equation (9). Once ΔA is calculated this way, the size of the windfall V_0 associated with long-run change Δu can be found. As might be expected, the relationship between the size of the windfall and the long-run change Δu generally depends on the adjustment dynamics of the model; steady-state real consumption depends on how much gets consumed along the path to the steady state.

Because of this difficulty of linking V_0 to the steady state, we will conduct analysis by taking as exogenous the long-run change $\Delta\lambda$ (equivalently Δu). Then, having solved for the adjustment path and the path of foreign asset accumulation, we can derive the associated size of the windfall, V_0 . Conceptually, V_0 is the exogenous variable, but analysis is greatly simplified by working this way round.

4. Absorbing the windfall

When the windfall becomes known the present value budget constraint shifts outwards and the marginal utility of wealth λ decreases. Associated with this there is an upwards jump in

demand for non-tradables and the derived demand for labour in the sector. These demand effects change prices and wages and alter the rates of return on capital in each sector, setting in train a process of investment and capital adjustment which further change prices. Prices and wages eventually return to their initial values, \bar{p} , \bar{w} , and real consumption and capital stocks make the long-run changes described in the preceding section. The model contains two distinct mechanisms creating slow adjustment. One is the ‘home grown’ capital requirement that new investment requires non-traded goods. The other is that sunk physical capital depreciates slowly and cannot be sold. In the next sub-section we focus on the ‘home grown’ capital requirement by assuming that capital is used only in the expanding (non-tradable) sector. In section 4.2 we focus on depreciation of existing capital stock by assuming that capital is used only in the contracting (tradable goods) sector and then, in section 4.3, we combine these cases and return to the full model.

4.1. Capital used only in non-traded goods production: $K^N > 0, K^T = 0$

If the traded goods sector uses no capital then $c^T(r^T, w) = c^T(w) = 1$, so the wage is fixed at $w = \bar{w}$. With constant wage and no capital in the traded goods sector, the system reduces to equations (12) and (13) which become,

$$\dot{K}^N = \left\{ K^N r_p^N(p, \bar{w}) - [\lambda E(p)]^{-\sigma} E_p(p) \right\} / b_p^N(p) - \delta^N K^N \quad (12')$$

$$\dot{p} = \left[(r^* + \delta^N) b^N(p) - r^N(p, \bar{w}) \right] / b_p^N(p), \quad (13')$$

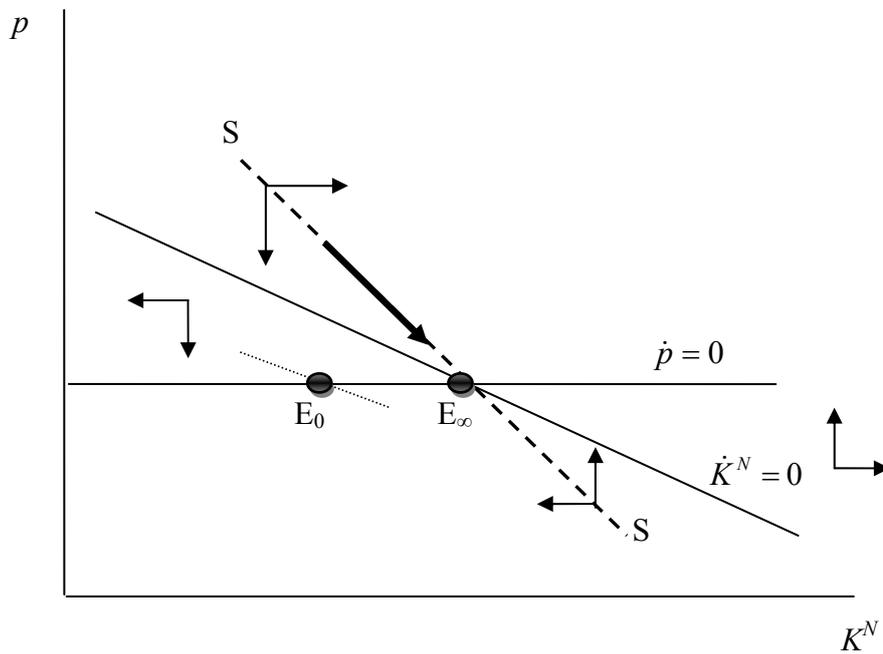
giving the dynamics of the capital stock in the non-traded sector, K^N , and the price of non-traded output, p .

The phase diagram for this pair of differential equations is given in fig. 1. The $\dot{K}^N = 0$ locus slopes downwards as illustrated. This is because increases in K^N and in p both raise the net supply of non-tradables available for investment.⁹ If the economy is above this locus, more non-tradables are produced than are consumed and needed to cover depreciation, so that the capital stock in the economy expands. The $\dot{p} = 0$ locus is horizontal. While the $\dot{p} = 0$ locus does not depend on K^N , higher p raises the return on investment, so is consistent with zero present value if capital losses are expected, i.e. $\dot{p} < 0$.

⁹ The partial derivatives of the right hand side of (12') with respect to p and K^N are both positive.

From an initial steady state E_0 , a reduction in the marginal utility of wealth $\Delta\lambda < 0$ pushes the stationary $\dot{K}^N = 0$ to the right, which raises the steady-state value of K^N and leaves that of p unaffected at point E_∞ . The equilibrium path involves on impact an upward jump in p and subsequently gradual reductions of p along the saddle-path SS back to its steady-state value. Along the saddle path K^N increases steadily to its new long-run value. We draw out the full implications for other variables below, but first give the formal analysis underpinning the phase diagram.

Figure 1: Capital and price dynamics after a windfall $K^N > 0, K^T = 0$



The dynamics of the linearised system are analysed in appendix 2. This is done with the minor simplification that capital goods are produced with fixed coefficients, so $b^N(p) = \beta p + (1 - \beta)1$ where β is the input of non-tradables per unit output and $(1 - \beta)$ is the input of tradables with $p^T = 1$. Appendix 2 shows that the (local) time paths of K^N and p are

$$K^N(t) = K_0^N + \Delta K^N (1 - \exp[-t\xi]), \quad p = \bar{p} + \left(\frac{2r_p^N - \beta(2\delta^N + r^*)}{S_p} \right) \Delta K^N \exp[-t\xi] \quad (17)$$

where the adjustment speed is $\xi = (r_p^N / \beta) - (\delta^N + r^*) > 0$, $S_p > 0$ is the slope of the supply of non-tradables available for use in investment, $S(p, K^N, \lambda) \equiv K^N r_p^N(p, \bar{w}) - [\lambda E(p)]^\sigma E_p(p)$ (see equation (12')) and the term in the round brackets in the second expression is positive.

These expressions reveal some interesting comparative dynamics. The share of non-traded goods in production of the capital stock, β , is crucial. The lower is this share the faster is the adjustment speed ξ , and if this share is zero, $\beta = 0$, then adjustment is instantaneous. This is the case outlined earlier; an economy which can import all its capital goods jumps to the new equilibrium. However, while lower β gives faster adjustment it also means a *larger* price jump on impact for a given (see appendix 2). Essentially, with lower β it becomes efficient to ramp up investment more rapidly. Since investment goods use non-tradables, there has to be a large increase in their price to accommodate this investment demand. The size of the initial price jump also depends on the responsiveness of net supply of non-tradables to prices; the greater this responsiveness, i.e. the larger is S_p , the smaller the price jump. Adjustment is also faster the lower are the rates of depreciation and interest, and the more sensitive is production of non-tradables to the capital stock (the higher the output-capital ratio), r_p^N .

Time paths of other variables are determined by their long-run values and the dynamics of K^N and p . For example, utility is $u = [\lambda E(p)]^{-\sigma}$ (equation (10)). As p declines towards its new long-run value, so utility increases, implying that any initial jump in u must leave it below its new steady-state value. Consumer expenditure is $u E(p) = \lambda^{-\sigma} [E(p)]^{1-\sigma}$. The path of this evidently depends on whether the intertemporal elasticity of substitution is greater or less than unity; if $\sigma < 1$, expenditure jumps to a level above its steady-state value, and then declines towards it as p falls. Importantly, we can establish that foreign assets start to be drawn down at date of impact and that the long-run value of A is less than the present value of the windfall at time zero, V_0 . The reason is the financing requirement of the increase in K^N . Some of the windfall has been used to build up the domestic capital stock, rather than left as interest-earning foreign assets.

Analytical results above were derived by linearising around the new steady states. Full equilibrium paths for the effects of a large windfall in the nonlinear model are shown in fig. 2. This (and following figures) utilises Cobb-Douglas preferences and production functions. The share of capital in production of non-tradables α^N is assumed to be 40%, while in tradables it is zero to give $K^T = 0$. Non-tradables account for 60% of consumption, and their share in capital goods is 75%. The rate of time preference and the interest rate are both set to 5% and time periods (horizontal axis) are set in corresponding units, so can be loosely interpreted as years. The intertemporal elasticity of substitution is $\sigma = 0.75$. The

initial (and long-run) wage, price, and income are all unity, so all units (except the changes of the top-left panel) are measured relative to initial income. The windfall is scaled such that utility increases by 25% between the initial value and new steady state.

Looking first at the top-left panel, the price of non-tradables jumps up by some 16% at the date the windfall is announced, and then declines back to its initial value. Real consumption, u , jumps up by a similar amount, and then continues to rise. The reason it fails to reach its permanent level immediately is that the high price of consumption makes it efficient to postpone some of the increase. However, with $\sigma < 1$ consumption expenditure, $uE(p)$ overshoots and then falls back. (If $\sigma > 1$ then $uE(p)$ would jump up by less than the long-run increment and increase thereafter). The top-right panel gives changes in investment flows. There is a jump in investment in non-tradables, I^N , which then asymptotes to its long-run value (greater than its initial level). There is, of course, no investment in the tradable sector. The dashed line in this panel gives the change in foreign assets, A . The high investment demand required for the economy's structural change means that these assets are run down following the windfall.

The bottom-left panel gives the economy's asset position. The economy's physical capital stock, K^N , increases as would be expected. The dashed line is the initial windfall, V_0 , computed to be that level which supports the 25% increase in steady-state utility. The line A is the combined asset value of the windfall and following changes in foreign assets. As we have seen $dA/dt < 0$ following the windfall, so A lies below V_0 . This makes the point that some of the windfall is used to build domestic capital stock, rather than all being held in foreign assets.

The final panel pulls together the income and expenditure side of the economy, illustrating variables as deviations from their initial value. The two dashed lines are nominal expenditures, the lower one being the increment in consumption expenditure (as in the top left-hand panel). To this is added the cost of the higher level of investment, together giving the change in gross national expenditure, $\Delta GNE = \Delta(uE + b^N(p)I^N)$. We see that this jumps by something over 40 percentage points of initial income, coming partly from real increases in u and I^N , and partly from the increase in p and the resulting price in investment goods. Solid lines give the income side of the economy. The annuity of the windfall is the horizontal line $r*V_0$, but foreign assets are reduced by the need to finance investment in the growing non-traded sector, so total foreign interest income $r*A$ falls gradually over time. To this is added the change in the value of output, giving the change in gross national income,

$\Delta GNI = r^* A + \Delta(px^N + x^T)$. The value of output jumps up considerably, due to increases in x^N and p , although x^T falls. The difference between GNE and GNI is of course the current account deficit (foreign financing), which corresponds exactly to the path of dA/dt in the panel above.

Figure 2: Adjustment with $K^N > 0, K^T = 0$ and constant wage

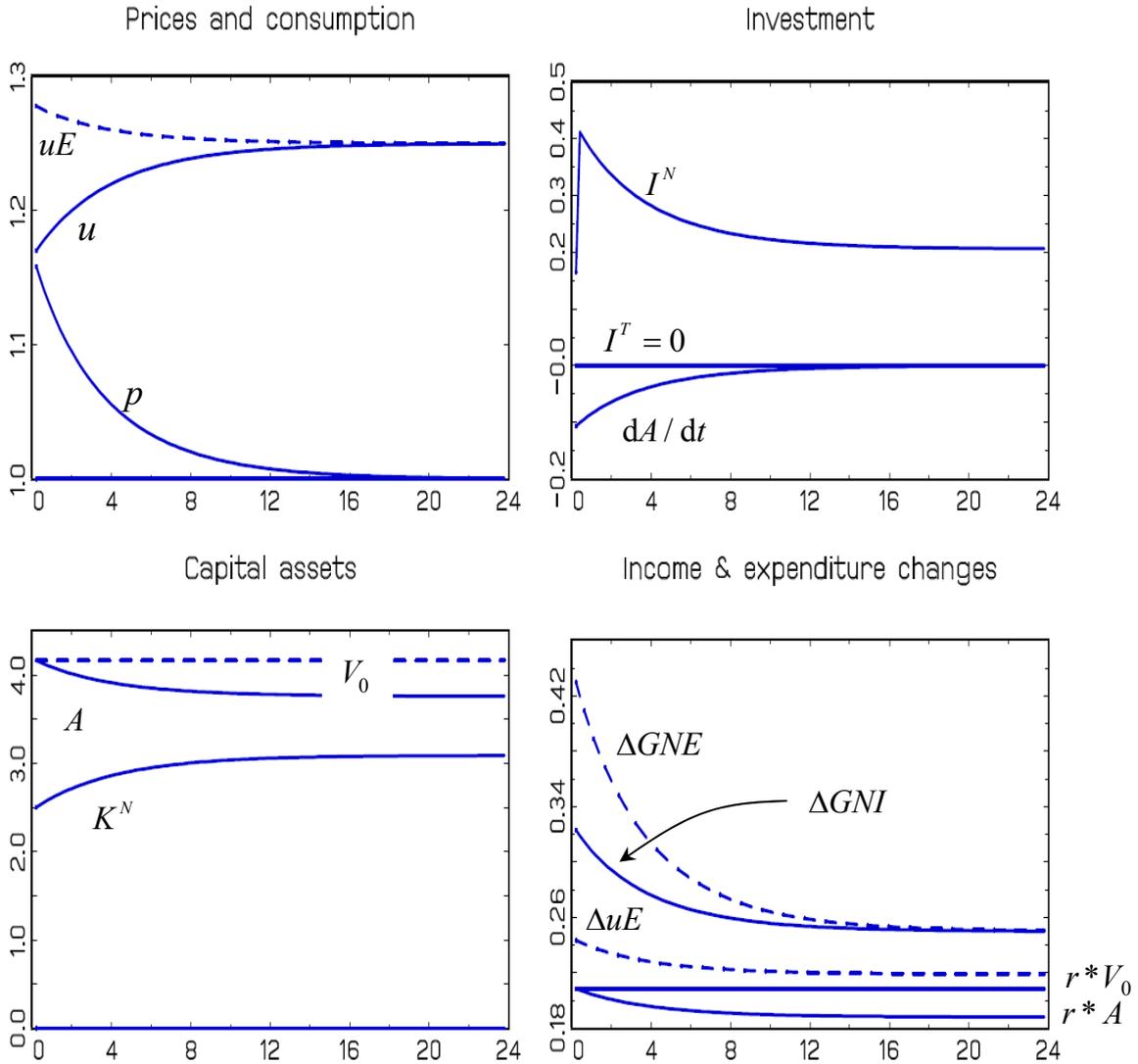


Fig. 2 gives the full time paths of variables, and table 2 gives just the impact and long-run responses. The permanent income value of the windfall is 20.8% of initial GDP and non-resource national income goes up by 32.3% on impact and 25% in the long run. The long-run effect comes from the increase in the physical capital stock, partly offset by a reduction in foreign assets A ; the short-run effect is a combination of price and quantity effects. On

impact, consumption expenditure rises by 24.3% of initial income and investment by 18.7%, both of these combining price and quantity increases, before falling back.¹⁰ The current account deficit and foreign financing amount to 10.7% of initial income. We stress that there are no distortions in our economy, so this is both the competitive equilibrium and the efficient outcome. Of course, the magnitude of effects in this case is exaggerated by the assumption that capital is only used in the non-traded sector.

Table 2: Income and expenditure changes with $K^N > 0, K^T = 0$ (% initial GNI)

	r^*V_0	r^*A	$\Delta(p^N x^N + x^T)$	ΔGNI	$\Delta(uE)$	$\Delta(b^N I^N + b^T I^T)$	ΔGNE
Short run	20.8%	20.8%	11.5%	32.3%	24.3%	18.7%	43.0%
Long run	20.8%	18.8%	6.2%	25.0%	21.9%	3.2%	25.0%

In summary then, the windfall causes a jump in both consumption and investment demand. Supply constraints mean that consumption does not jump all the way to its new steady state level, that there is an increase in the price of non-tradables (real appreciation), and that the economy runs a current account deficit, reducing its net foreign asset position in order to finance domestic investment. The price and current account effects unwind as the economy converges to the new steady state, while consumption continues to grow, adjusting to the new level of wealth.

4.2. Capital used only in traded goods production: $K^N = 0, K^T > 0$

The converse case has capital in the traded goods sector, but not in the expanding non-tradable sector. The main mechanism that we are studying – the constraint created by the need to produce home-grown capital for a growing sector – is therefore absent. However, adjustment is still not instantaneous because of sunk capital in the contracting sector. Relative price changes, in particular an increase in the wage, are induced by the windfall-induced boom in demand and are needed to draw labour out of this sector, as we saw in section 2. By gradually running down capital installed in the tradable sector and shifting

¹⁰ The long-run increase in consumption expenditure of 21.9% of initial GDP corresponds to an increase in real consumption of 25% of its initial value.

labour to the non-tradable sector, the initial wage hikes and appreciation of the real exchange rate are gradually reversed.

Non-tradables are now produced by labour alone, and we denote labour input per unit non-tradable output by constant a^N . The system now has differential equations for K^T and p ,

$$[\dot{K}^T + \delta^T K^T] b_p^T(p) = x^N - [\lambda E(p)]^{-\sigma} E_p(p) \quad (12'')$$

$$\dot{p} b_p^T(p) = (r^* + \delta) b^T(p) - r^T(w) \quad \text{if } I^T > 0. \quad (14'')$$

The non-traded sector sets price proportional to the wage, $p = w a^N$, and labour market clearing, (15), becomes

$$x^N = [L + K^T r_w^T(w)] / a^N. \quad (15'')$$

Response to the windfall now takes place through two phases. In the first $I^T = 0$, equation (14'') does not hold, and the capital stock depreciates according to $\dot{K}^T = -\delta^T K^T$. Using (15'') in (12'') non-traded goods market clearing is $[L + K^T r_w^T(w)] / a^N = [\lambda E(p)]^{-\sigma} E_p(p)$, so prices and wages (with $w = p/a^N$) solve this equation. This shows that, on impact, the reduction in λ leads to an increase in demand for non-tradables and hence an increase in p and w . Afterwards, p and w gradually fall back as K^T depreciates, more labour is reduced for the non-tradable sector and supply of non-tradables expands. When p and w reach \bar{p} , \bar{w} investment starts.¹¹ In this second phase prices and wages are constant, so equation (12'') with (15'') is a single differential equation in K^T which converges asymptotically to its new steady-state value.

Fig. 3 illustrates the equilibrium path. The behaviour of real consumption and the real exchange rate is similar to that in the preceding case, but the mechanism is quite different. Both p and w jump up to secure the transfer of labour from the tradable sector to the non-tradable. In the first phase, while $w > \bar{w}$, there is no investment, $I^T = 0$ (see top-right panel), and the economy runs down its capital stock (lower-left panel). As a consequence the economy builds up capital assets in excess of the windfall, manifest in $dA/dt > 0$, a current account surplus which leads to a terminal stock of foreign assets, A , greater than the value of

¹¹ In the first phase the right-hand side of (12'') is positive and declining, and the left hand side is negative. The present value of investment is therefore negative until new long run equilibrium prices are reached.

the windfall. On the lower-right panel we see that the increment to GNE is less than the increment to consumption, reflecting the zero level of investment. GNI exceeds GNE, this giving current account surplus and accumulation of foreign assets.

Figure 3: Adjustment with $K^N = 0, K^T > 0$ and p proportional to w .

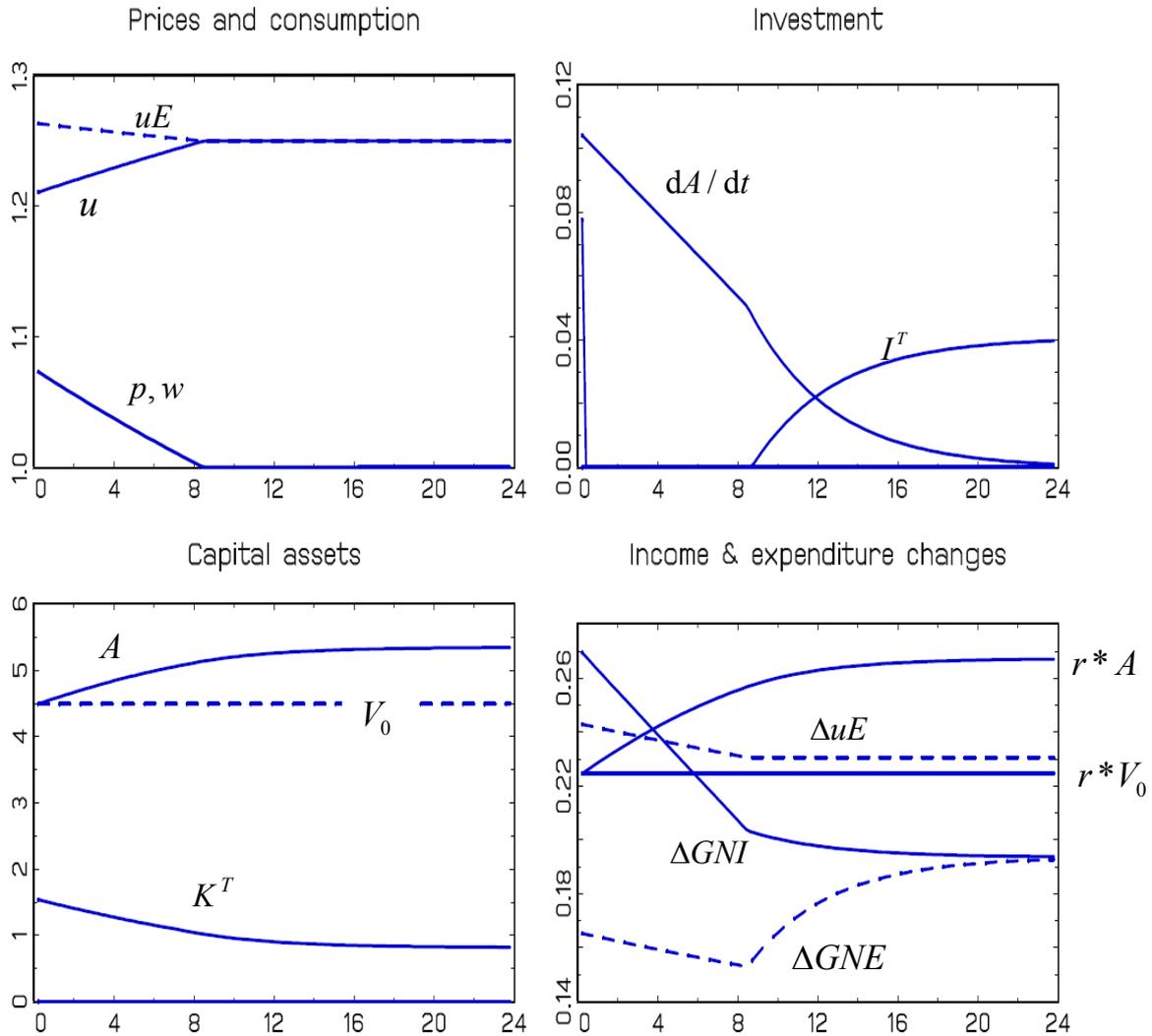


Table 3 gives the exact value of the changes on impact and in the long run. The main difference from table 2 is that when capital is only used in the non-tradable sector the economy invests a lot in the domestic economy and therefore ends up with less foreign assets than the windfall, but when capital is only used in the tradable sector it winds investment projects down and therefore ends up with more assets abroad.

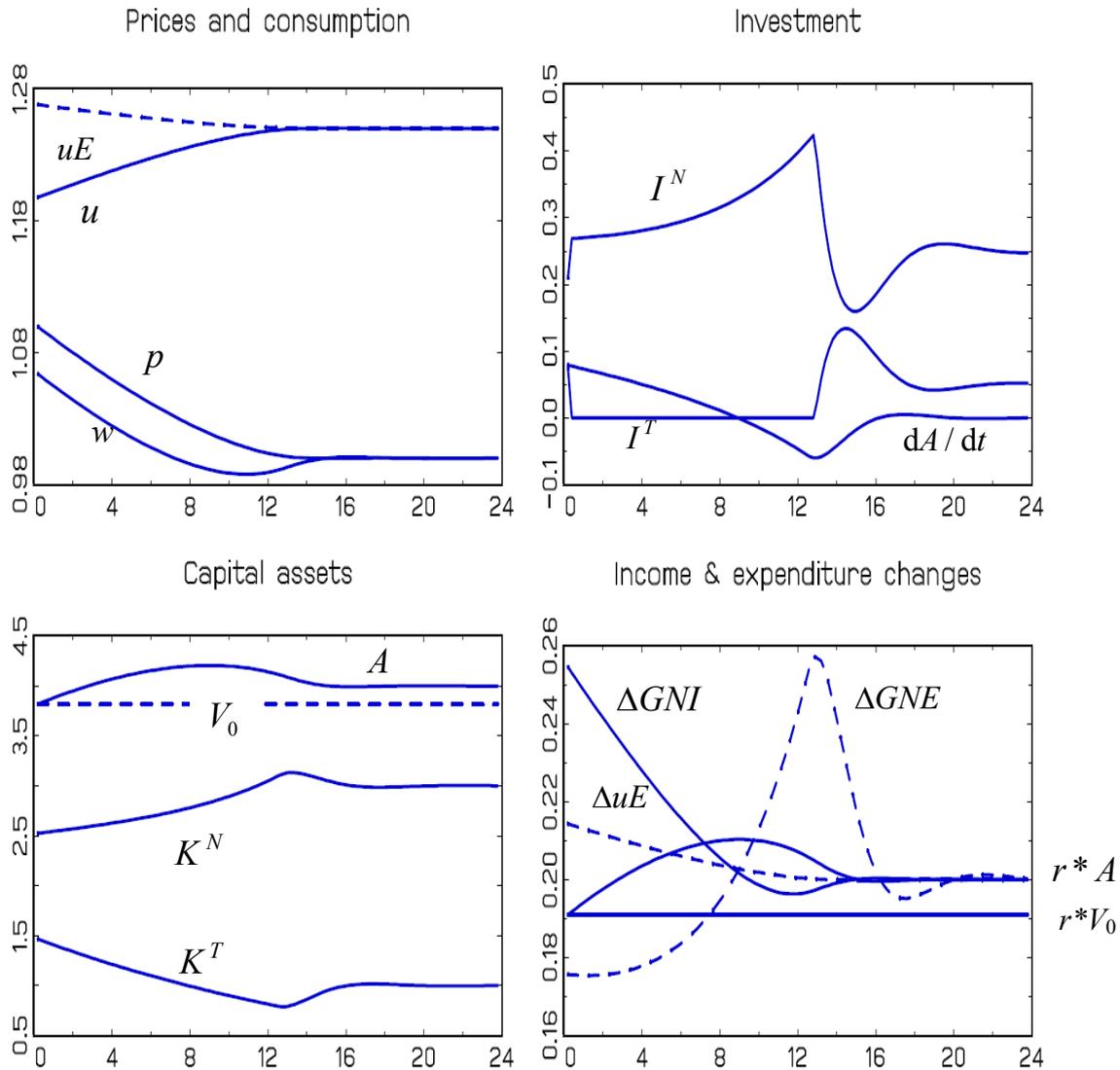
Table 3: Income and expenditure changes with $K^N = 0, K^T > 0$ (% initial GNI)

	r^*V_0	r^*A	$\Delta(p^N x^N + x^T)$	ΔGNI	$\Delta(uE)$	$\Delta(b^N I^N + b^T I^T)$	ΔGNE
Short run	22.4%	22.4%	4.5%	26.9%	24.3%	-7.8%	16.5%
Long run	22.4%	26.7%	-7.5%	19.2%	23.1%	-3.9%	19.2%

4.3. Capital in both sectors: $K^N > 0, K^T > 0, b_p^N = b_p^T > 0$

We now allow both sectors to use capital. We focus on the central case in which both sectors have the same technologies with, for numerical purposes, the capital share in production set at 40% and share of non-tradables in capital set at 75%. This symmetry means that there is no long-run change in the economy's total physical capital stock, $\Delta K^N + \Delta K^T = 0$.

The dynamic system is now the full set of equations (12) – (15). The adjustment of the economy is illustrated in fig. 4 and the impact and long-run effects are given in table 4. We see a combination of the results from the previous two subsections. There is a finite period during which $I^T = 0$ and this is accompanied by an upwards jump and rising path of investment in the non-tradable sector, $I^N > 0$. The price of non-tradables and the wage both jump up on impact, but p increases by more than does w . This is because the release of labour from the tradable sector requires an increase in w , while capital accumulation in non-tradables requires an increase in p/w . It is noteworthy that along the path w falls below its long-run value, this reflecting the fact that two quite different adjustment processes are going on – release of labour from the tradable sector and capital accumulation in the non-tradable. A corollary of this price and wage path is that the capital stock in non-tradables overshoots its long-run value. As in previous cases, the price path and associated path of $E(p)$ means that consumption only jumps a fraction of the way to its new long-run value, continuing to rise thereafter.

Figure 4: Response to foreign exchange windfall; non-tradables in all capital goods

While the composition of the economy's physical capital stock is changing, it is also altering its holdings of foreign assets. The top-right panel indicates that the economy initially has a current account deficit followed by a surplus. This is seen most clearly in the bottom-right panel, in which the difference between GNI and GNE starts positive and then follows damped oscillations in its convergence. The corresponding asset path (integrating along the current account) is given in the lower-left panel; the initial increases in total foreign assets, A , are not totally reversed by following current account deficits, so has long-run value $A > 0$. Recall that, in this case, the total physical assets of the economy are unchanged, $\Delta K^N + \Delta K^T = 0$. The economy's total assets therefore increase, implying that absorption costs cause a given size change in long run Δu to be attained with smaller windfall V_0 plus

some further foreign asset accumulation. The reason is the slow build up of consumption; it is efficient to run a payments surplus and place some income in foreign assets while the economy is undergoing adjustment to absorb its windfall. Notice that some of this is run down (the hump in the time path for A), indicating that wealth is ‘parked’ abroad on a temporary basis during the adjustment period.

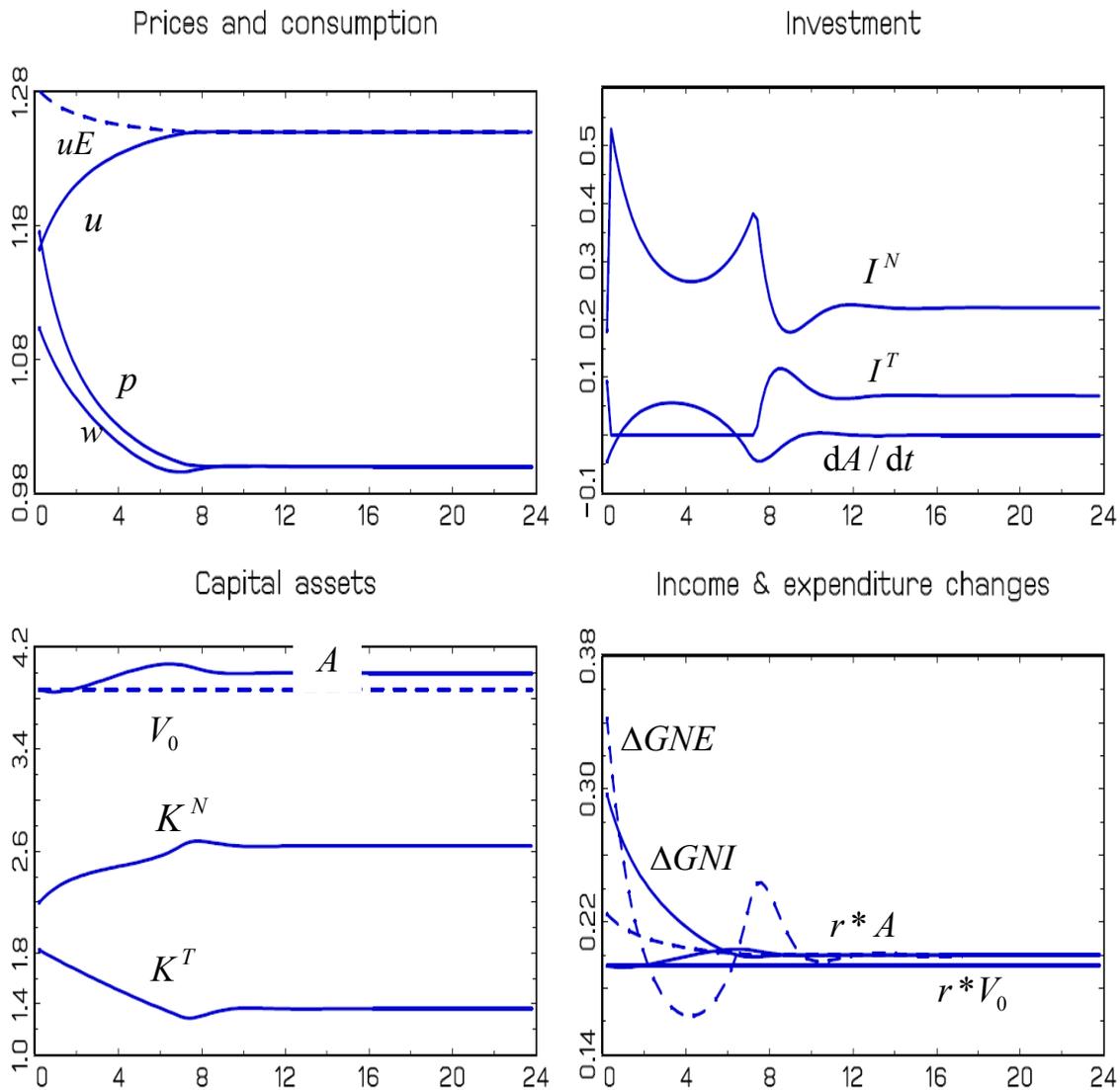
Table 4: Income and expenditure changes with $K^N > 0, K^T > 0$ (% initial GNI)

	r^*V_0	r^*A	$\Delta(p^N x^N + x^T)$	ΔGNI	$\Delta(uE)$	$\Delta(b^N I^N + b^T I^T)$	ΔGNE
Short run	19.1%	19.1%	6.4%	25.5%	21.4%	-3.8%	17.6%
Long run	19.1%	20.0%	0%	20.0%	20.0%	0%	20.0%

4.4. Determinants of the speed of absorption

The preceding sub-sections indicate how results depend on the capital intensities of the expanding and contracting sectors. How do outcomes, in particular the speed of absorption, depend on other parameters? The share of non-tradables in the production of capital goods is critical, as demonstrated analytically in section 4.1, where we showed that a lower share of non-tradables (β) means faster adjustment, but also a larger initial jump in prices and hence smaller initial jump in utility (as the price effect is large relative to the income effect). This finding is confirmed in fig. 5 below, in which parameters are as in fig. 4 except that the share of non-tradables in capital goods production is reduced from 75% to 30%. We see that the time taken for real consumption and prices to come close to their long-run values is approximately halved, but that price responses and investment spikes are amplified. In line with our earlier discussion it is now efficient to adjust investment more rapidly but, to accommodate this, the initial jump in prices is larger and in real consumption is smaller.

Varying other parameters produces results in line with expectations. For example, the figures above are based on Cobb-Douglas technologies, and simulations with CES technologies indicate that price jumps are larger and adjustment slower the lower is the elasticity of substitution between labour and capital in production, or between tradables and non-tradables in capital goods.

Figure 5: Small share of non-tradables in investment goods

4.5. Investment, assets, and the permanent income hypothesis

The permanent income hypothesis (PIH) suggests that the economy should adjust its asset holdings such that the new level of permanent consumption is equal to the permanent income from the windfall, r^*V . In its simplest form, it also suggest the windfall should be held primarily in the form of foreign assets, since adding to the domestic capital stock will reduce the rate of return below the world rate of interest. How does this relate to our analysis?

The first difference concerns the composition of the assets accumulated. Our approach makes it clear that structural change creates demand for investment in the domestic economy, so it may be appropriate to run a current account deficit and reduce foreign asset holdings. Domestic financing needs depend on the capital intensities of the two sectors, with

the overall physical capital stock rising (falling) if the capital labour ratio is higher (lower) in the non-traded good sector. The need to expand the capital stock in the growing sector may make it efficient to run a current account deficit to finance investment, giving a correspondingly lower stock of foreign assets, A . These points caution against equating saving out of a windfall with accumulation of foreign assets. Clearly, if structural change increases demand for physical capital (at rate of return at least as great as r^*) then this demand should be met by domestic investment, and accommodated by a correspondingly lower stock of foreign assets.

The second difference concerns the level of assets. Absorption problems means that the total asset stock (physical + foreign) of the economy may go up by more or less than the value of the windfall, which departs from the Hartwick (1977) logic of reinvesting all resource rents in non-resource assets. In tables 2 and 4 total assets increase by more than the windfall alone (as the long-run increase in GNI is greater than the permanent income of the windfall, r^*V), so there is net saving relative to the permanent income hypothesis. Intertemporal efficiency requires that consumption starts relatively low and rises as supply constraints are relaxed and the marginal cost of consumption falls. It may thus be efficient to 'park' resource revenues in overseas assets while the economy is addressing the constraints it faces in building up spending. In the central case where both sectors have identical technologies the current account of the balance of payments should be in surplus in early years. Indeed, this is the IMF definition of incomplete absorption: a foreign exchange flow is said to be fully absorbed if not offset by accumulation of reserves or other foreign assets. The trade deficit is initially less than resource revenues (imputed to be r^*V) so foreign assets are accumulated and then run down.

Perhaps most importantly, these adjustments in the economy are accompanied by large price changes and the Dutch disease symptoms of appreciated real exchange rate and declining tradable sector. However, these are temporary symptoms of the economy's adjustment given the absorption constraints that it faces. Furthermore, since our economy has no market failures the adjustment paths we have found are the first-best efficient responses to the windfall.

5. Gainers, losers, policy

5.1. *Gainers and losers*

Instantaneous adjustment to a windfall of foreign exchange, achieved through perfect inter-sectoral and international mobility of capital, means that adjustment is achieved without changing factor prices or causing capital gains or losses; the windfall simply accrues in a lump-sum manner to households in the economy. Absorption and slow adjustment superimpose on this gains and losses from price changes, and these take the following form. Workers' nominal wages increase during adjustment, but this is offset by at least as large an increase in the price of non-tradables. The net effect on the real wage is ambiguous, depending on the composition of consumption; for example in fig. 4 there is, on impact a higher real wage for a short period followed by a real wage reduction. Capital owners in the traded goods sector take a capital loss on impact. They face a constant output price and higher wage so the present value of returns on their capital assets falls. In contrast, capital owners in the non-traded good sector experience a capital gain. Since investment continues in this sector the present value of future earnings equals the cost of capital equipment, so the capital gain on impact equals the increase in the cost of capital equipment. This is a real capital gain if capital equipment is more intensive in the non-traded good than is consumption. Of course, the capital gain accrues only to holders of capital goods at the date of the windfall. Future investors are unaffected, as the present value of investments is zero.

5.2. *Policy analysis*

Our model contains no market imperfections; the equilibrium is efficient and there is no scope for policy to raise the consumers' objective, the present discounted value of real consumption. Nevertheless, there are many pressures on government to intervene during a process of structural change. In this sub-section we discuss policy within the framework of our model, and in the next we step outside it to a wider discussion of policy issues.

Many countries seek to cushion declining sectors, following policies that protect incomes and perhaps also jobs in the declining sector. What, in the present model, are the effects of such policies? We have explored the effect of having an employment subsidy in the tradable sector which is implemented at the date of the windfall and then declines exponentially. The policy creates a wedge between wages paid in non-traded and traded sectors, and slows down the release of labour from the tradable sector. It reduces the return on investment in non-tradables, and thereby reduces the rate of investment, I^N . However,

while it raises the return on investment in tradables it does not do so by enough to cause investment in the sector to take place.¹² Total investment in the economy is therefore reduced, and absorption slowed down; for example, K^T follows the same downwards path as on fig. 4 but for a longer period, thereby reaching a lower level before I^T commences and the turning point in K^T is reached.

While the employment subsidy slows down adjustment, it has a positive short-run impact on factor returns. Nominal wages and the price of non-tradables are increased and there is an unambiguous increase in the real wage since the effect of the policy is to restrict the supply of labour to the non-tradable sector. However, this increase in real wage is quite short-lived as lower investment and capital stock in the non-traded sector reduce demand for labour. The subsidy also alters the pattern of capital gains and losses that occur on impact. Capital losses in the traded sector are reduced, and can even be turned into capital gains; the present value of earnings can increase, although by less than the cost of capital so the present value of new investment remains negative. Capital gains in the non-traded sector become larger, because p and hence the prices of the capital goods that they are holding increase. Hence, the effect of the wage subsidy is attractive – in the short-run – to all agents in the economy, raising (or at least not reducing) their factor returns. Of course, aggregate utility is reduced (the employment subsidy is a distortion), and the subsidy has to be financed by taxes which fall on some factor owners at some date. However, the tax can be postponed into the future, for example by taxing future income from the windfall.

This illustrates the pressure that there may be on government to slow down absorption. It is in stark contrast to a policy of subsidising employment in the expanding sector. While such a policy would raise real wages it would reduce returns to capital in the tradable sector and, by making p lower than it otherwise would have been, reduce the capital gains accruing in the non-traded sector.

5.3. Policy extensions

We have argued that absorption constraints arise from bottlenecks in the supply of non-traded goods due to the fact that these goods themselves require non-traded goods for their production. How might these constraints be alleviated? Broadly, there are three ways. One is by being better able to reallocate resources (capital and labour) from other sectors. A second is by facilitating investment in the non-traded sector. And the third is by importing

¹² Marginal changes in returns have an effect on I^N , but since the return to I^T is strictly negative so I^T remains zero even for quite large wage subsidies.

these constraining ‘non-traded’ goods. We discuss each in turn, noting first that an aggregate model of the type developed here fails to capture the extent to which constraints vary across different activities. In reality, some bottlenecks will be acute (often urban infrastructure in booming resource cities) and others not, and investment should of course be directed to where its marginal social value is greatest.

Our approach has assumed that capital, once installed is immobile. In reality some parts of capital – for example office space, or human capital with general skills – can be used in either sector, and reallocating such capital relaxes absorption constraints. Dynamics of this case (i.e. sectorally mobile capital equipment that requires non-traded goods) is analysed in appendix 3. If the non-tradable sector is capital intensive we get the usual Dutch disease dynamics; if the tradable sector is capital-intensive the real exchange rate and the wage do not adjust and the windfall results in a gradual winding down of capital and import of tradables. To the extent that policies can facilitate the shunting of capital from the traded to the non-traded sector, absorption constraints will obviously be alleviated. If the tradable sector is capital intensive, there are no absorption constraints whatsoever.

Adjustment will be more rapid if obstacles to investment in non-tradables are removed, and this is an important potential area of policy action. For example, there may be barriers to entry, as owners of capital in the sector seek to preserve the value of their capital gains. Barriers may be created by government regulation, distortionary tax regimes, failures in domestic land or capital markets, or by uncertainties about the future development of the economy. A good business environment is particularly important as prompt investments are needed to handle the transition. Public investment also plays a role, as constraints will often be due to shortages of publically provided capital, be it road and transport infrastructure, electric power and other utilities, or worker training and human capital. It also requires that government is able to plan and undertake effective projects – itself an activity that it is likely to be capacity constrained. The windfall itself is, in principle, a means of funding tax reductions and public infrastructure. However, for this to occur requires that the windfall accrues to government and is not diverted to unproductive rent-seeking activities. For example, a ruler faced with losing office may invest excessively in partisan, illiquid projects rather than in a sovereign wealth fund which can easily be raided by a political rival (e.g. Collier et al., 2009). With big windfalls it is tough to spend the revenue efficiently and avoid corruption, so the quality of home-grown capital might go down and the cost of supplying

non-tradable capital up. Also, there may be an appropriation sector drawing production factors away from more productive sectors.¹³

Finally, adjustment is speeded up if key constraints can be relaxed by imports. What is tradable and what is non-tradable is partly a matter of technology, and partly a matter of politics. For goods, there will be intense pressure for domestic content requirements and perhaps import restrictions to make sure that the windfall benefits domestic producers. The message of this paper is that such pressures should be evaluated very carefully to ensure that inputs to investment goods are not subject to such restrictions. The issue is even more sensitive when it concerns the international mobility of people. Countries with small populations and large windfalls – the Gulf States for example – have followed a strategy of importing skilled labour. Such a policy is not likely to be acceptable in a populous country with surplus labour and a much smaller windfall relative to the size of its population, such as Nigeria. Once again, targeting is important, identifying key constraints and selectively using imported labour to develop local capacity.

6. Concluding comments

We have drawn out the implications of a micro-founded model of the absorption constraints faced by an economy adjusting to a windfall of aid or natural resource revenues. We have four main findings. The first is that if home-grown capital is needed for development the windfall induces a sharp appreciation of the real exchange rate, although this is temporary; as home-grown capital is accumulated the real exchange rate gradually depreciates back to its equilibrium level. Second, on impact, real consumption jumps part but not all the way to its new steady-state value. Consumers see the path of the real exchange rate and domestic prices and postpone some of the increase in real consumption, although nominal consumption may overshoot its new long-run value.

The third result concerns financing of structural change. In a central case, the economy will run a current-account surplus in early years, followed by a period of smaller deficit. Essentially, it is optimal to ‘park’ some of the windfall in foreign assets while absorption problems are being sorted out. However, this result depends on the levels of investment that are required to adjust to the new position. If the non-traded sector is capital

¹³ An increase in commodity prices then lowers (boosts) the opportunity cost of appropriation, i.e. wages, and thus increases (dampens) conflict and efficiency losses if the commodity is capital-intensive (labour-intensive) (Dal Bó and Dal Bó, 2010).

intensive there will be an initial investment surge which should be financed by foreign borrowing and a current account deficit. Finally, we identify crucial parameters that determine the magnitude of these effects. Chief amongst these is the extent to which output growth is dependent on locally produced output. An economy that can import all the goods it needs for production faces no bottlenecks while an economy that has to build up its own capacity faces a slower adjustment process.

Together, these results indicate that the simple predictions of the permanent income hypothesis, i.e. investing the windfall so that the interest can pay for a permanent increase in consumption after the windfall has dried up, will generally not hold as the economy moves along an adjustment path. This suggests that use of the permanent income hypothesis as a basis for policy, as suggested in studies of the International Monetary Fund (e.g., Davis et al., 2002), needs modification in the light of absorption issues.

Many extensions suggest themselves. These include a richer modelling of capital goods. For example, a fuller input-output matrix, or making more of the fact that the non-traded share varies across capital goods. It may be particularly high in structures and, if structures have slower depreciation than tradable equipment, then this will tend to worsen absorption problems. Labour supply may also be endogenous, particularly in a surplus labour economy which may mitigate the problem. Above all, work needs to be done to draw out policy implications. We have worked with a perfect undistorted economy in which there are no efficiency gains to be made from the use of policy instruments. In practise there are multiple distortions and public expenditure – e.g. on infrastructure – has an important role to play in facilitating adjustment to a new and richer equilibrium.

Appendix 1: Steady-state capital stocks (section 3.3)

In long-run equilibrium equation $\dot{K}^N = \dot{K}^T = 0$ and equation (12) and (15) become $r_p^N K^N = \delta^N K^N b_p^N(\bar{p}) + \delta^T K^T b_p^T(\bar{p}) + u E_p(\bar{p})$ and $L + K^N r_w^N(\bar{p}, \bar{w}) + K^T r_w^T(\bar{w}) = 0$, respectively. Taking changes between long-run equilibria (given unchanged prices and techniques of production) and abstracting from exogenous changes in L gives

$$\Delta K^N = \frac{E_p(\bar{p})\Delta u}{r_p^N - \delta^N b_p^N(\bar{p}) + \delta^T b_p^T(\bar{p})r_w^N / r_w^T}, \quad \Delta K^T = \frac{-(r_w^N / r_w^T)E_p(\bar{p})\Delta u}{r_p^N - \delta^N b_p^N(\bar{p}) + \delta^T b_p^T(\bar{p})r_w^N / r_w^T}.$$

The denominator of the expressions must be positive for the economy to yield positive net output. Since $E_p(\bar{p}) > 0$ and $(r_w^N / r_w^T) > 0$, an increase in real consumption associated with a windfall induces an increase in K^N and a fall in K^T . The steady-state effect on the total capital stock is positive if $-r_w^N < -r_w^T$ as may be seen from

$$\Delta K = \frac{((r_w^T - r_w^N) / r_w^T)E_p(\bar{p})\Delta u}{r_p^N - \delta^N b_p^N(\bar{p}) + \delta^T b_p^T(\bar{p})r_w^N / r_w^T}.$$

Appendix 2: Dynamics of the linearised system (section 4.1)

We analyse the system

$$\begin{bmatrix} \dot{K}^N \\ \dot{p} \end{bmatrix} = \begin{bmatrix} a & b \\ 0 & d \end{bmatrix} \begin{bmatrix} K^N - (K_0^N + \Delta K^N) \\ p - \bar{p} \end{bmatrix}.$$

Routine calculation (which may be easily checked by differentiation and substitution) indicates that the solution for an unanticipated windfall occurring at time zero equals

$$K^N(t) = K_0^N + \Delta K^N (1 - e^{-\xi t}) \quad \text{and} \quad p(t) = \bar{p} + \left(\frac{a-d}{b} \right) \Delta K^N e^{-\xi t}.$$

With fixed coefficients in the production of capital goods $p = (1-\beta) + \beta p = 1 + \beta(p-1)$. Linearising the model of section 4.1 then gives $a = r_p^N / \beta - \delta > 0$, $b = S_p / \beta > 0$ and $d = (r^* + \delta) - r_p^N / \beta < 0$, where the

function $S(p, K) = K^N r_p^N(p, \bar{w}) - [\lambda E(p)]^{-\sigma} E_p(p)$ defines the excess of non-tradable production over consumption of non-tradables. Since the determinant of the Jacobian matrix of this system ad is negative, the system displays saddlepoint dynamics. The speed of adjustment ξ is given by the modulus of the eigenvalue of the Jacobian matrix with negative real part, that is using $a+d=r^*$,

$$\xi = -\frac{1}{2}r^* + \frac{1}{2}\sqrt{r^{*2} - 4ad} = -\frac{1}{2}r^* + \frac{1}{2}\sqrt{r^{*2} + 4\left[\left(\frac{r_p^N}{\beta}\right) - \delta^N - r^*\right]\left[\left(\frac{r_p^N}{\beta}\right) - \delta^N\right]} = \left(\frac{r_p^N}{\beta}\right) - (\delta^N + r^*) > 0.$$

From appendix 1 we know that $\Delta K^N = \frac{E_p(\bar{p})\Delta u}{r_p^N - \delta^N \beta}$, hence the initial price of non-tradables

equals $p(0) = \bar{p} + \left(\frac{2r_p^N - \beta(2\delta^N + \rho)}{r_p^N - \delta^N \beta} \right) \frac{E_p(\bar{p})\Delta u}{S_p}$. Hence, $\frac{\partial p(0)}{\partial \beta} = - \left(\frac{\rho r_p^N}{(r_p^N - \delta^N \beta)^2} \right) \frac{E_p(\bar{p})\Delta u}{S_p}$

is negative for a positive value of Δu .

Appendix 3: Intrasectoral capital mobility

If capital (not just investment) is perfectly mobile between the two sectors, capital returns in the two sectors must be equalised. Suppose all capital is home grown, so that $b^N = b^T = p$. Suppose Cobb-Douglas production functions with different capital shares α^N in the non-traded sector and α^T in the traded sector. Intra-sectoral labour and capital mobility require that the wages and returns on capital in the two sectors are equalised:

$$w = p \left[\frac{(1-\alpha^N)K^N}{L^N} \right]^{\alpha^N} = \left[\frac{(1-\alpha^T)K^T}{L^T} \right]^{\alpha^T} a \text{ and } r = p\alpha^N \left[\frac{L^N}{(1-\alpha^N)K^N} \right]^{1-\alpha^N} = \alpha^T \left[\frac{L^T}{(1-\alpha^T)K^T} \right]^{1-\alpha^T}.$$

Hence, we obtain conditional labour demands and factor prices:

$$L_N = (1-\alpha^N) \left(\frac{\alpha^N}{\alpha^T} \right)^{\frac{\alpha^T}{\alpha^N - \alpha^T}} p^{\frac{1}{\alpha^N - \alpha^T}} K_N, \quad L_T = (1-\alpha^T) \left(\frac{\alpha^N}{\alpha^T} \right)^{\frac{\alpha^N}{\alpha^N - \alpha^T}} p^{\frac{1}{\alpha^N - \alpha^T}} K_T,$$

$$w = \left(\frac{\alpha^N}{\alpha^T} \right)^{\frac{\alpha^N \alpha^T}{\alpha^T - \alpha^N}} p^{\frac{\alpha^T}{\alpha^T - \alpha^N}} \text{ and } r = \alpha^N \left(\frac{\alpha^N}{\alpha^T} \right)^{\frac{(1-\alpha^N)\alpha^T}{\alpha^N - \alpha^T}} p^{\frac{1-\alpha^T}{\alpha^N - \alpha^T}}.$$

Appreciation of the real exchange rate induces expansion of production of non-tradables. If the non-traded sector is relatively capital intensive ($\alpha^N > \alpha^T$), this leads to an increase in the rate of return on capital, decline of the wage and the labour-capital ratio in both sectors increases. If the non-traded sector is relatively labour intensive ($\alpha^T > \alpha^N$), the wage rises, the return on capital falls and the labour-capital ratio in both sectors falls.

Using the above expressions in the labour market equilibrium condition $L^N + L^T = L$, we obtain an expression for the share of the non-traded sector in total home-grown capital:

$$\frac{K_N}{K} = \alpha^N \left[\frac{1 - \alpha^T - \left(\frac{\alpha^T}{\alpha^N} \right)^{\frac{\alpha^N}{\alpha^N - \alpha^T}} p^{\frac{1}{\alpha^T - \alpha^N}} \left(\frac{L}{K} \right)}{\alpha^N - \alpha^T} \right] \equiv \Omega(p, K).$$

Hence, an appreciation of the real exchange rate leads to more home-grown capital being allocated to the production of non-tradables. If the non-traded production sector is more capital intensive than the traded production sector ($\alpha^N > \alpha^T$), a lower supply of labour or a higher stock of capital in the economy induces a bigger allocation of capital to the non-traded sector. If the non-traded production sector is relatively labour intensive ($\alpha^N < \alpha^T$), more capital is allocated to the traded sector.

Using the condition for equilibrium in the market for non-tradables and the condition that the return on home-grown capital r/p must equal the interest charge plus depreciation charge minus capital gains on capital, we obtain the state-space equations of the model:

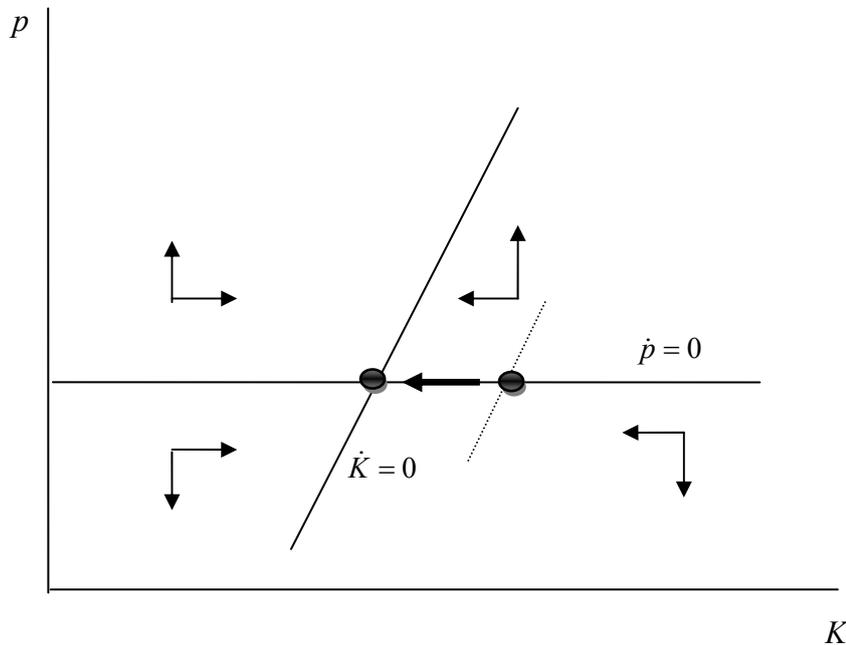
$$\dot{K} = \left[\left(\frac{\alpha^N}{\alpha^T} \right)^{\frac{\alpha^T}{\alpha^N - \alpha^T}} p^{\frac{1}{\alpha^N - \alpha^T}} \Omega(p, K) - \delta \right] K - E'(p) [\lambda E(p)]^{-\sigma}$$

$$\frac{\dot{p}}{p} = r^* + \delta - \alpha^N \left(\frac{\alpha^N}{\alpha^T} \right)^{\frac{(1-\alpha^N)\alpha^T}{\alpha^N - \alpha^T}} p^{\frac{1-\alpha^N}{\alpha^N - \alpha^T}}.$$

The wage is endogenous and proportional to $p^{\frac{\alpha^T}{\alpha^N - \alpha^T}}$, so if $\alpha^N > \alpha^T$ it moves inversely with the real exchange rate p . Of course, in sections 4.1 with $\alpha^T = 0$ the wage was pinned down by technology while in section 4.2 with $\alpha^N = 0$ the wage was proportional to the real exchange rate. Both may be viewed as the extreme polar cases of the present model. Immediately upon the discovery of a windfall, the wage rises and the relative price of non-tradables is bid up. Afterwards, the wage and the price of non-tradables gradually fall back to their initial levels.

As is clear from inspection of the state-space equations, the phase diagram and dynamics are given by fig. 1 (with total home-grown capital K rather than K^N on the horizontal axis) provided that $\alpha^N > \alpha^T$ as is the case in sections 4.1. However, the exponents of p change sign and $\Omega_K < 0$ if the relative capital intensity of the two sectors is reversed, $\alpha^N < \alpha^T$. These are the result of Stolper-Samuelson effects capturing the effects of goods price on factor prices, and give rise to two regimes with different adjustment dynamics.¹⁴ If the traded goods sector is more capital intensive than the non-traded sector ($\alpha^N < \alpha^T$) as in section 4.2, the real exchange does not adjust at all in response to a windfall of foreign exchange as can be seen from the phase-plane diagram portrayed in fig. 6.

Figure 6: Dynamics if the traded good sector is capital intensive, $\alpha^N < \alpha^T$



As the home-grown investment goods are mostly needed in the traded rather than in the non-traded sector and traded sector output can fall by importing more tradables, there are no

¹⁴ This also occurs in the literature on growth models of dependent economies (e.g. Turnovsky, 2009).

absorption problems. The Stolper-Samuelson effect implies that a real exchange rate appreciation (higher p) reduces the real return on capital for the non-traded sector if $\alpha^N < \alpha^T$, which implies that p is rising above the $\dot{p} = 0$ stationary. The saddle-path is now simply the $\dot{p} = 0$ stationary, so that there is no change in prices p and real consumption u immediately jumps up to its new level. The capital stock K has to shrink to its new steady-state value. This is accompanied by slow reallocation from K^T to K^N .

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