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TIME-INTENSIVE R&D AND UNBALANCED TRADE*

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Abstract

This paper highlights a novel mechanism that generates global imbalances. It develops a general equilibrium trade model with one of two countries having a comparative advantage in a sector whose production is characterized by (i) rapid, anticipated demand growth and (ii) large up-front R&D costs. International funding of the accruing R&D costs generates capital inflows in the R&D stage, which are balanced by subsequent outflows. Importantly, sector-level growth does not generate growth differentials between countries, typically regarded as rationales of global imbalances. Additionally, it is shown that a trade surplus can coincide with appreciations of the real exchange rate. I argue that Switzerland's trade surplus, which was driven to record heights during 2010-2014 by pharmaceutical exports, exemplifies this mechanism. Calibrating the model to Swiss trade flows underpins this argument.

Keywords: Unbalanced trade, setup costs, R&D costs
JEL Classification: F12, F41

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1 Introduction

Trade theory does not require that cross-border trade flows be balanced period by period. Large current account and trade imbalances, however, are typically observed with concern. Concerns arise, because global imbalances can result in disruptive and potentially painful adjustments.¹ Distinguishing between harmful imbalances that entail the danger of costly disruptions and *natural imbalances* that arise under optimal international borrowing and lending is of obvious relevance for policy makers.

This paper documents one particular source of *natural imbalances* that previous literature has ignored. It shows how unbalanced trade arises when a sector, which is characterized by cost- and time-intensive R&D activity and exhibits rapid (e.g., demand-driven) growth. Countries with a comparative advantage in this specific sector will, (anticipating demand growth) intensify according R&D activity. Part of the R&D investments are financed on the international capital market, thereby generating capital inflows to the mentioned countries, which consequently run trade deficits in these R&D periods. Conversely, there are capital outflows in later periods, mirrored by the corresponding trade surpluses.

The theory is framed in the classical two-country model of trade in varieties à la Krugman (1980), which is amended in two dimensions. First, countries trade in two periods, which allows for non-trivial international borrowing and lending. Second, varieties are produced in two different sectors under costly entry for an unlimited pool of identical entrants. The two sectors differ in the nature of setup costs: in one of them, the sector D , setup costs accrue up front; the other sector exhibits standard per-period fixed costs. Consequently, firms in sector D are set up in the initial period but produce in the second period, whereas the other firms are set up and produce in each of the periods. I assume that only country 1 can produce in sector D and that it therefore covers world demand. In the first period, country 1 thus allocates part of its resources to cover setup costs in sector D . International capital markets channel savings to foreign investors to country 1's D -sector to (partly) cover up-front setup costs. Thus, capital flows to country 1 and its position of net foreign assets decreases as it runs a trade deficit. In the second period, the firms in sector D produce; profits are used

¹Obstfeld and Rogoff (2005) see adjustment shocks and possible economic "traumas [for] the United States and foreign economies" as a reasonable adjustment scenario. See, e.g., Roubini and Sester (2005), Obstfeld and Rogoff (2007), and Lane and Milesi-Ferretti (2014).

to service returns on investment and country 1 runs a trade surplus.

It is worth stressing that growth of the R&D-intensive sector, which is required for the mechanism to operate, does not necessarily generate differences in GDP growth across countries. Hence, the theory is not merely a variation of the well-studied effect by which cross-country differentials in income growth generate global imbalances (see Obstfeld and Rogoff 1996). Instead, it shows that sector-specific technological progress in one country can generate imbalances without any cross-country growth differentials. The underlying reason for this observation is that shifts in factor allocation and countries' specialization patterns transmit the gains from sector-specific productivity growth in one country across borders, thereby levelling growth across countries.² The model shows that such intertemporally optimal imbalances would be classified as *harmful* under a conventional assessment based on cross-country growth (and savings) rates. As a corollary, the argument also shows that distinguishing natural and harmful imbalances may be even tougher than previously thought.³

In addition, the model delivers valuable insights related to exchange rate dynamics. Specifically, it predicts that a country's trade surplus may coincide with an appreciation of its real exchange rate (defined as the ratio of local over foreign consumer-price adjusted wages). The real exchange rate of a country with a growing R&D-intensive sector, as described above, appreciates over time through a combination of the two following antagonistic forces. First, wages in such a country tend to fall relative to foreign wages because of the capital outflows in the second period.⁴ Second, wages tend to increase by the home market effect as physical production expands in the second period. These effects make the local price index fall, thereby increasing real wages. These second forces turn out to be dominant, and the real exchange rate of the country appreciates. In sum, exchange rate appreciations concur with positive net exports.

Finally, it seems important to stress that the theory crucially rests on the assumption that the R&D-intensive sector exhibits a period of accelerated growth. This growth may be driven by either technological progress (the

²Indeed, in the absence of trade costs, growth and savings rates equalize across countries.

³Blanchard and Milesi-Ferretti 2009 write that "assessing whether imbalances were good or bad, and the role of distortions and risks, turns out to be far from obvious in practice, and thus a major source of disagreements."

⁴This first force, labeled the *secondary burden* of international transfers by Keynes, is extensively studied. See Keynes (1929), Corsetti et al (2013) and Land and Milesi-Ferretti (2012).

costs of R&D drops and suddenly becomes profitable), or it may result from an increase in the demand for the R&D-intensive goods (demographic change or per capita income growth change expenditure patterns). In either scenario, the economy is not in steady state, and there is not a constant stream of capital outflow that is balanced by a constant stream of capital inflows.

To illustrate the theory with a real-world example, the model is calibrated to Switzerland's trade flows of the past two decades. The Swiss economy is particularly well-suited to illustrate the theoretical mechanism because it satisfies the key preconditions: large shares of its export basket consist of pharmaceutical goods. The pharmaceutical sector, in turn, has experienced a period of accelerated demand growth in the recent past and is, moreover, R&D intensive. Indeed, the pharmaceutical industry is the paradigm of an R&D-intensive sector, with a R&D phase that is not only cost-intensive but that extends over particularly long periods of time.⁵ In combination, these features make the pharmaceutical sector in general and the Swiss economy in particular a fitting example of the situation described in the theoretical setup.

Calibrated to match the increase of the share of pharmaceutical products in the Swiss export basket, the model performs well in predicting the increase of total trade under a wide range of reasonable parameter values. At the same time, the terms of trade (domestic over foreign wages) and the real exchange rate (price adjusted wage ratio) are predicted to remain essentially unchanged. Finally, these key results – moderate changes of the terms of trade and real exchange rates at simultaneously large movements in the trade balance – generalize to the case when the country considered is relatively large.

The present paper connects to various bodies of literature. First, it relates to the extensive work on the global imbalances and external adjustments, and thus to the classical contribution by Obstfeld and Rogoff (1996), who highlight how the forces of consumption smoothing generate global borrowing and lending. A large portion of recent studies are motivated by the US current account deficit (which constitutes the largest share of global imbalances).⁶ The key culprits are typically found in the strong reserve accumulation of Asian (particularly Chinese) central banks and in

⁵See Klette (1996), Acemoglu and Linn (2004) and Deutsche Bank (2012).

⁶See Edwards (2005), Obstfeld and Rogoff (2005a, 2007) Lane and Milesi-Ferretti (2014), Corsetti and Konstantinou (2012) and Blanchard et al (2005).

US fiscal policy, which are sometimes regarded as the major contributors of the recent financial crisis.⁷ Most studies argue that for ultimate rebalancing, substantial depreciations of the USD is needed. Reviewing this literature, Blanchard and Milesi-Ferretti (2010) generally distinguish between the category of harmful imbalances, which are typically attributed to the realm of policy misalignments and systemic risks and are beneficial, or *good imbalances*, which arise, e.g., due to differentials in economic growth rates, demographic dynamics and other factors that affect national savings and investment opportunities. Recent prominent examples of the latter are Caballero et al (2008) and Mendoza et al (2009). Other prominent explanations rely on the *global savings glut*, valuation effects or financial development.⁸ The current paper adds to this literature by highlighting one specific source of *good imbalances*. Specifically, it stresses that cross-country differences in aggregate growth rates are generally not enough to detect the sources of good imbalances when these are based on sector-specific growth.

The current study also contributes to the analysis of global imbalances through the lens of trade-based models such as those of Dekle et al (2007) and (2008) and Corsetti et al (2007 and 2013).⁹ These studies typically build on static trade models and examine the implications and channels of eliminating current account imbalances, but they remain silent about the underlying causes of the latter.¹⁰ The current paper adds to this literature in two dimensions. First, it abandons the static modelling setup that is usually explored and thus allows for the endogenous motives of cross-border capital flows and unbalanced trade.¹¹ Second, it unbundles the sectorial dimension and identifies sectoral growth in specific industries as one particular source of global imbalances. It thus takes on the challenge of Dekle et al (2007), who, observing that trade imbalances remain imperfectly understood, ”defer modeling their determinants for future work.”

The current paper also relates to the literature on the cyclicity of trade

⁷See, in particular, Chinn and Ito (2008) and Roubini and Sester (2005).

⁸See Bernanke 2005, McGrattan and Prescott 2010 Gourinchas and Rey 2007, Chakraborty and Dekle 2008, Caballero et al 2008, Mendoza et al 2009 and Prades and Rabitsch 2012.

⁹See also Boyd et al (2001), Kappler et al (2013) and Chinn and Wei (2013) for discussions on exchange rates and current account adjustments, which go back to Ohlin (1929) and Keynes (1929).

¹⁰Under such an approach, the effects in the short and the long run are usually distinguished by considering either perfect or no factor mobility (Dekle et al (2008)), or, alternatively, either exogenous or endogenous number of firms (Corsetti et al (2007)).

¹¹In an extension, Corsetti et al (2013) present one of the rare exceptions to the static setup.

flows, which received much attention during the recent trade collapse (as in Alessandria et al. (2010) Domit and Shakir (2010), Crowley and Luo (2011), Engel and Wang (2011) and Bems et al. (2012). Closely related to the current paper, Erceg et al. (2008) argue that investment shocks may generate external adjustments and show that these adjustments do not need to come about with real exchange rate fluctuations. Regarding framework and analytical tools, the present paper is closest to Corsetti et al (2007, 2013), who analyze enhanced versions of the Krugman (1980) type of model. Although these authors explore the effects of firm entry in tradable and non-tradable sectors under largely exogenous adjustments, the present paper goes one step further by endogenizing trade imbalances under cross-country differentials in investment opportunities.

Lastly, the general principle of the paper is also reminiscent of the *hysteresis* or *beachhead effect* (see Baldwin (1988), Dixit (1989) Baldwin and Krugman (1986), by which sunk costs that are incurred in the past partly decouple the trade flows from actual exchange rate fluctuation. Referring to this phenomenon, Baldwin and Krugman (1986) argue that, "[o]nce foreign firms have invested in marketing, R&D, reputation, distribution networks, etc., they will find it profitable to remain in the U. S. market even at a lower exchange rate."

The remainder of this paper is structured as follows. Section 2 presents the theory, section 3 illustrates a calibration exercise to the Swiss economy and, in particular, to its pharmaceutical sector, and section 4 concludes.

2 The Model

There are two countries, indexed by $i = 1, 2$, and populated with identical individuals. The world economy deviates from the standard Krugman (1980) setup in two dimensions. First, countries produce and trade in two periods, indexed by $t = 0, 1$. The main implication of this assumption is that trade is balanced on an intertemporal basis but not necessarily period-by-period. Second, there are two sectors, indexed by $S = C, D$. One of the sectors (sector C) is subject to the standard period-by-period fixed costs; in the other (sector D) setup costs need to be incurred one period in advance of physical production.

2.1 Model Setup

Preferences. The representative consumer in country i derives a sub-utility from consumption of varieties produced by firm k in sector C (c_{ik}) and consumption of varieties produced by firm k' in sector D (d_{ik}). The according sub-utility is

$$\bar{C}_{i,t} = \left[\int c_{ik,t}^{1-1/\varepsilon} dk + \int d_{ik,t}^{1-1/\varepsilon} dk \right]^{\varepsilon/(\varepsilon-1)} \quad (1)$$

and total utility is

$$U_i = \ln(\bar{C}_{i,1}) + \delta \ln(\bar{C}_{i,2}) \quad (2)$$

where δ is the discount factor of individuals.

Denoting wages with $w_{i,t}$, consumers maximize utility (2) subject to the budget constraints

$$\sum_{t=0}^1 R^{-t} \left\{ \int q_{ik,t}^D d_{ik,t} dk + \int q_{ik,t}^C c_{ik,t} dk - w_{i,t} \right\} \leq 0 \quad (3)$$

where $q_{jk,t}^S$ is the consumer price of variety k of sector S produced in country j , charged at time t ; R is the gross nominal interest rate between both periods.

Technology. The amount $x_{k,t}$ of sector C -variety k is produced through

$$L_{k,t} = \alpha^C + \beta x_{k,t} \quad (4)$$

in Home and Foreign. I assume that only country 1 can produce varieties of sector D according to

$$x_{k,t} = \begin{cases} L_{k,t}/\beta & \text{if } L_{k,t-1} = \alpha^D \\ 0 & \text{if } L_{k,t-1} < \alpha^D \end{cases} \quad (5)$$

That is, in the D -sector fixed costs are incurred in the period before actual production. In $t = 0$ no firms are active in the D -sector and no D -type varieties can be produced.¹²

¹²Notice that this setup admits interpretations of growth in the D -sector due to technological change (e.g., when α^D drops from prohibitive levels in periods $t < 0$) or demand shocks (when a weighting factor in the aggregator (1) increases from zero in periods $t < 0$ to one as specified here).

2.2 Optimization

Product Prices. Factory-gate prices of varieties produced in country i are

$$p_{i,t}^S = \frac{\varepsilon}{\varepsilon - 1} \beta w_{i,t} \quad (6)$$

as usual under constant elasticities. They are, in particular, equal in both sectors. Cross-border trade is subject to standard iceberg-type trade costs, captured by $\tau \geq 1$, so that local consumer prices equal $p_{i,t}^S$ and abroad, consumer prices equal $p_{i,t}^S$ times the factor τ .

Country Bundles. By (6), producer prices in both sectors are identical within a period, $p_{i,t}^C = p_{i,t}^D = p_{i,t}$, so that the ideal producer price index of goods produced in country i at time t is

$$P_{i,t} = \left[\int_{B_{it}^C \cup B_{it}^D} (p_{jt})^{1-\varepsilon} dj \right]^{1/(1-\varepsilon)} = \frac{\varepsilon}{\varepsilon - 1} \beta w_{i,t} n_{it}^{1/(1-\varepsilon)} \quad (7)$$

where B_{it}^S is the set of varieties of sector S produced in country i at time t and n_{it} is the total mass of varieties (of both sectors) produced in country i at time t . Consumer prices of the corresponding consumption bundles $C_{ij,t}$ are equal to these prices (7) times gross trade costs τ , if applicable. The consumption bundle of individuals in country i of goods produced in country j at time t can be written as

$$C_{ij,t} = c_{ij,t} n_{jt} \quad (8)$$

This expression uses that, as prices (6) equalize across sectors, individual consumption does as well ($d_{ij,2} = c_{ij,2}$). Finally, aggregate consumption $\bar{C}_{i,t}$ from (1) is

$$\bar{C}_{i,t} = \left[C_{i1,t}^{1-1/\varepsilon} + C_{i2,t}^{1-1/\varepsilon} \right]^{\varepsilon/(\varepsilon-1)} \quad (9)$$

Expenditures. Consumer decision involves intertemporal expenditure. Preferences (2) imply that expenditure shares in period t is $\delta^t/(1 + \delta)$. In period $t = 0$ the net present value of an individual's income is $W_i = w_{i,0} + R^{-1}w_{i,1}$, where R is the gross nominal interest rate. Thus, expenditures of individuals are, when expressed in period 1-dollars

$$e_{1,t} = \frac{(\delta R)^t}{1 + \delta} w_{1,0} \left(1 + \frac{\Omega}{R} \right) \quad \text{and} \quad e_{2,t} = \frac{(\delta R)^t}{1 + \delta} w_{1,0} \left(\omega_0 + \frac{\Omega}{R} \omega_1 \right) \quad (10)$$

where relative wages

$$\Omega = w_{1,1}/w_{1,0} \quad \text{and} \quad \omega_t = w_{2,t}/w_{1,t} \quad (11)$$

are introduced.

Demand for Bundles. Consumer optimization of (2) under (9) subject to the budget constraint $\sum_t R^t (P_{i,t} C_{ii,t} + \tau P_{j,t} C_{ij,t}) \leq W_i$ (with $j \neq i$) implies

$$\frac{C_{ii,t}}{C_{ij,t}} = \left(\frac{P_{i,t}}{\tau P_{j,t}} \right)^{-\varepsilon} \quad (12)$$

Expenditure on consumption goods in country i at time t is now with (7) (see Appendix)

$$e_{i,t} = \tau P_{j,t} C_{ij,t} \left(\left(\frac{w_{i,t}}{\tau w_{j,t}} \right)^{1-\varepsilon} \frac{n_{it}}{n_{jt}} + 1 \right) \quad (13)$$

Notice that combining (7), (10) and (13) determines consumption of the bundles $C_{ij,t}$ as a function of relative wages Ω and ω_t , and the number of firms $n_{i,t}$. Determining these latter endogenous variables is the aim of the next steps.

Savings and Capital Flows. In period $t = 0$, individual savings in either country equals wage income minus expenditure ($s_{i,0} = (w_{i,0} - e_{i,0})$) or with (10)

$$s_{1,0} = \frac{w_{1,0}}{1+\delta} \left(\delta - \frac{\Omega}{R} \right) \quad \text{and} \quad s_{2,0} = \frac{w_{1,0}}{1+\delta} \left(\delta \omega_0 - \frac{\Omega}{R} \omega_1 \right) \quad (14)$$

Because investment in the D -sector is the only form of savings, all savings in country 2 ($S_{2,0} = L_2 s_{2,0}$) are invested in country 1. In period $t = 1$, returns on investments are collected, and country 1's capital outflow is $RS_{2,0}$. Together, country 1's net capital inflows in period t are thus with (14)

$$CF_{1,t} = (-R)^t S_{2,0} = (-R)^t L_2 \frac{w_{1,0}}{1+\delta} \left(\delta \omega_0 - \frac{\Omega}{R} \omega_1 \right) \quad (15)$$

Investment in the D -Sector. Denote the number of active D -type firms in country 1 in period 1 with n^D so that the total costs of generating

blueprints in the D -sector is $\alpha^D n^D w_{1,0}$.¹³ This sum must be equal the total value of savings in period 0, which is (use $S_{i,0} = L_i s_{i,0}$ and (14))

$$S_{1,0} + S_{2,0} = L_1 \frac{w_{1,0}}{1 + \delta} \left(\delta [1 + \lambda \omega_0] - \frac{\Omega}{R} [1 + \lambda \omega_1] \right) \quad (16)$$

where $\lambda = L_2/L_1$. Together, this yields

$$n^D = \frac{L_1}{\alpha^D} \frac{1}{1 + \delta} \left(\delta [1 + \lambda \omega_0] - \frac{\Omega}{R} [1 + \lambda \omega_1] \right) \quad (17)$$

The obvious conditions for an interior solution to prevail are $n^D > 0$ and, by the resource constraint, $\alpha^D n^D < L_1$, or

$$0 < \delta [1 + \lambda \omega_0] - \frac{\Omega}{R} [1 + \lambda \omega_1] < 1 + \delta \quad (18)$$

At the firm level, free entry in the D -sector requires that the entry costs ($w_{1,0} \alpha^D$) be just covered by the present value of future operating profits. The CES aggregator (1) implies that the share of operating profits in firm revenue equals $1/\varepsilon$: This, in turn, implies that the present value of future profits equals $R^{-1}(1/\varepsilon)x_{1,1}^D \beta w_{1,1}$. Equating costs to profits and using (11) implies

$$\alpha^D = (\Omega/R) (\beta/\varepsilon) x_{1,1}^D$$

In $t = 1$, firm output for the C - and for the D -sector firm is identical ($x_{1,1}^C = x_{1,1}^D$), and, moreover, $\beta/\varepsilon x_{1,1}^C w_{1,1} = \alpha^C w_{1,1}$ holds by free entry in the C -sector. Thus, the equality

$$\Omega/R = \alpha^D/\alpha^C \quad (19)$$

follows. Clearly, in the cases where $\Omega/R < \alpha^D/\alpha^C$, investment costs are not covered, and the D -sector is idle.¹⁴ Alternatively, $\Omega/R > \alpha^D/\alpha^C$ cannot be an equilibrium, because more D -type firms would enter the market.

Equation (19) conveniently pins down the wage evolution in country 1 by requiring $\Omega = w_{1,1}/w_{1,0} = R\alpha^D/\alpha^C$. The crucial observation is that in the interior solution in period 1, a worker (or entrepreneur) is indifferent between buying a blueprint of the D -good at the production cost plus interest $Rw_{1,0}\alpha^D$ or paying a worker (or inventor) to set up a C -firm at cost $w_{1,1}\alpha^C$.

¹³The number of D -type firms in country 2 or in period $t = 0$ is zero by construction.

¹⁴That case occurs if α^D is too large to justify investment. It can be excluded, however, when α^D is small enough.

2.3 Equilibrium

The Trade Balance. In period t the value of country 1's net exports is $NE_{1,t} = \tau (L_2 P_{1,t} C_{21,t} - L_1 P_{2,t} C_{12,t})$ or, with (10) and (13)

$$NE_{1,t} = \frac{w_{1,0} L_1}{1 + \delta} (\delta R)^t \left(\lambda \frac{\omega_0 + \frac{\Omega}{R} \omega_1}{\left(\frac{\omega_t}{\tau}\right)^{1-\varepsilon} \frac{n_{2,t}}{n_{1,t}} + 1} - \frac{1 + \frac{\Omega}{R}}{\left(\frac{1}{\tau \omega_t}\right)^{1-\varepsilon} \frac{n_{1,t}}{n_{2,t}} + 1} \right) \quad (20)$$

Trade must be balanced on an intertemporal basis, which implies $NE_{1,0} + R^{-1} NE_{1,1} = 0$.

A convenient observation is that country 1's trade surplus must correspond to the capital outflows $NE_{1,t} = -CF_{1,t}$ from (15), or

$$\lambda \frac{\omega_0 + \frac{\Omega}{R} \omega_1}{\left(\frac{\omega_0}{\tau}\right)^{1-\varepsilon} \frac{n_{2,0}}{n_{1,0}} + 1} - \frac{1 + \frac{\Omega}{R}}{\left(\frac{1}{\tau \omega_0}\right)^{1-\varepsilon} \frac{n_{1,0}}{n_{2,0}} + 1} = -\lambda \left(\delta \omega_0 - \frac{\Omega}{R} \omega_1 \right) \quad (21)$$

$$\lambda \frac{\omega_0 + \frac{\Omega}{R} \omega_1}{\left(\frac{\omega_1}{\tau}\right)^{1-\varepsilon} \frac{n_{2,1}}{n_{1,1}} + 1} - \frac{1 + \frac{\Omega}{R}}{\left(\frac{1}{\tau \omega_1}\right)^{1-\varepsilon} \frac{n_{1,1}}{n_{2,1}} + 1} = \frac{\lambda}{\delta} \left(\delta \omega_0 - \frac{\Omega}{R} \omega_1 \right) \quad (22)$$

Because Ω/R is determined by (19), this system of equations determines relative wages ω_t as a function of model parameters and the number of firms $n_{i,t}$. These variables will be determined next.

The Number of Firms. Consider first the number of firms in country 2. Recall that a firm's operating profits as share of revenues equals $1/\varepsilon$. Because operating profits just cover a firm's fixed costs $w_{1,t} \alpha^C$ in country 2 on a period-by-period basis, a firm's revenue must be $\varepsilon w_{1,t} \alpha^C$ within each period t . The total revenues of all C -sector firms in country 2 and period t are thus $n_{i,t} \varepsilon w_{i,t} \alpha^C$. This expression must be equal to the aggregate wagebill, $w_2 L_2$, so that

$$n_{2,t} = L_2 / (\varepsilon \alpha^C) \quad (23)$$

Computing the number of active firms in country 1 is more complicated because entry in the D -sector is based not on period-by-period profits but on the net present value of operating profits. I will restrict the analysis of equilibria with interior solutions, i.e., in which C -varieties will be produced in country 1 in both periods. The relevant conditions will be formulated below.

Letting $L_{1,t}^C$ the amount of labor employed in the C -sector, the same argument as above implies $L_{1,t}^C = \varepsilon \alpha^C n_{1,t}^C$. In period $t = 0$, when $\alpha^D n^D$ units

of labor are devoted to invention of blueprints in the D -sector in country 1, labor market clearing implies

$$L_1 = \varepsilon \alpha^C n_{1,0}^C + \alpha^D n^D$$

Now observe that a C -firm's labor demand for production excluding setup costs equals its total labor demand $\varepsilon \alpha^C$ minus employment for setup costs α^C . In period $t = 1$, a firm's employment for production is thus $(\varepsilon - 1) \alpha^C$. This statement holds not only for C -firms but also for D -firms, because marginal costs and demand are the same across sectors. Hence, labor market clearing in $t = 1$ implies

$$L_1 = \varepsilon \alpha^C n_{1,1}^C + (\varepsilon - 1) \alpha^C n^D = \alpha^C [\varepsilon n_{1,1}^C + (\varepsilon - 1) n^D]$$

The two preceding equations can be rewritten as

$$\varepsilon \alpha^C n_{1,0} = L_1 - \alpha^D n^D \quad (24)$$

$$\varepsilon \alpha^C n_{1,1} = L_1 + \alpha^C n^D \quad (25)$$

where $n_{i,t}$ is newly introduced as the total number of firms in country i . Note that setting up n^D D -type firms in period $t = 0$ is equivalent to subtracting $\alpha^D n^D$ units of labor from the labor force in period 0 and adding $\alpha^C n^D$ labor units in period 1.

Using (19) and (23), the two equations above imply

$$\frac{n_{1,0}}{n_{2,0}} + \frac{n_{1,1}}{n_{2,1}} \frac{\Omega}{R} = \frac{1 + \Omega/R}{\lambda}$$

Equations (17), (23), (24) and (25) determine the number of firms as a function of relative wages and thus close the model.

With (17), (19) and (23), equations (24) and (25) are

$$\frac{n_{1,0}}{n_{2,0}} = \frac{\lambda^{-1}}{1 + \delta} \left(1 + \frac{\Omega}{R} - \lambda \left(\delta \omega_0 - \frac{\Omega}{R} \omega_1 \right) \right) \quad (26)$$

$$\frac{n_{1,1}}{n_{2,1}} = \frac{\lambda^{-1}}{1 + \delta} \left(\frac{\Omega}{R} \right)^{-1} \left(\delta \left(1 + \frac{\Omega}{R} \right) + \lambda \left(\delta \omega_0 - \frac{\Omega}{R} \omega_1 \right) \right) \quad (27)$$

With these expressions, the system of two equations (21) and (22) can be written in terms of parameters and the two remaining endogenous variables, ω_t .

The resulting system determines ω_t , which then pins down $n_{1,t}$ through (23), (26) and (27); all other endogenous variables follow.

2.4 Economic Aggregates

Note that in all equations above the variables Ω and R appear only in combination, i.e., as the fraction Ω/R . The reason is that in the absence of nominal rigidities, the nominal interest rate is undetermined as long as the level of prices (or wages) are not fixed for all periods. Formally, it is therefore safe to set $R = 1$. With this normalization, key economic aggregates can be computed in the following.

Output. Country 1's share of world GDP in period t is

$$y_{1,t} = \frac{w_{1,t}L_1}{w_{1,t}L_1 + w_{2,t}L_2} = \frac{1}{1 + \omega_t\lambda} \quad (28)$$

Exports. Its export shares are with (10) and (13)

$$ex_{1,t} = \frac{\tau L_2 P_{1,t} C_{21,t}}{w_{1,t}L_1} = \lambda \frac{(\delta/\Omega)^t}{1 + \delta} \frac{\omega_0 + \Omega\omega_1}{(\omega_t/\tau)^{1-\varepsilon} \frac{n_{2t}}{n_{1t}} + 1}$$

The size of the D -sector in period 1 is, when measured in sales, with (17) and (25)

$$\frac{n^D}{n_{1,1}} = \varepsilon \frac{1 + \lambda\omega_0 - \Omega/\delta [1 + \lambda\omega_1]}{\Omega + 1 + \lambda [\omega_0 - \Omega/\delta\omega_1]}$$

Real Exchange Rate. I follow the convention that the real exchange rate, RER, is defined as the relative price of consumption across border (see Corsetti et al 2013): For country 1, the real exchange rate is thus

$$RER_{1,t} \equiv \frac{w_{1,t}/P_{1,t}}{w_{2,t}/P_{2,t}} = \frac{P_{2,t}/P_{1,t}}{\omega_t}. \quad (29)$$

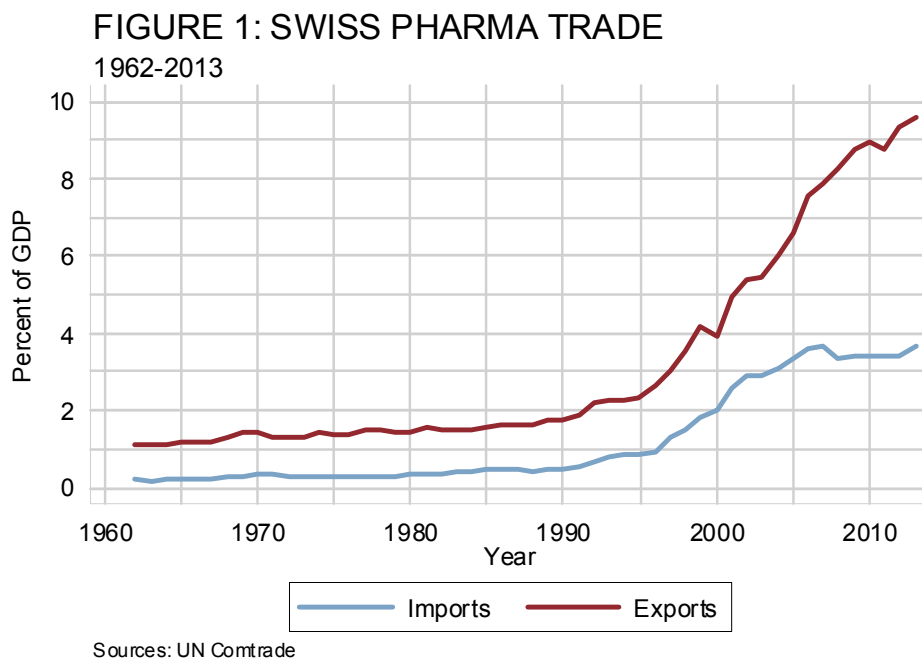
These economic indicators will be highlighted in the calibration exercise below.

3 Calibration of the Model

In this section, I present a calibration exercise of the model developed so far.

3.1 The choice Switzerland's pharma exports

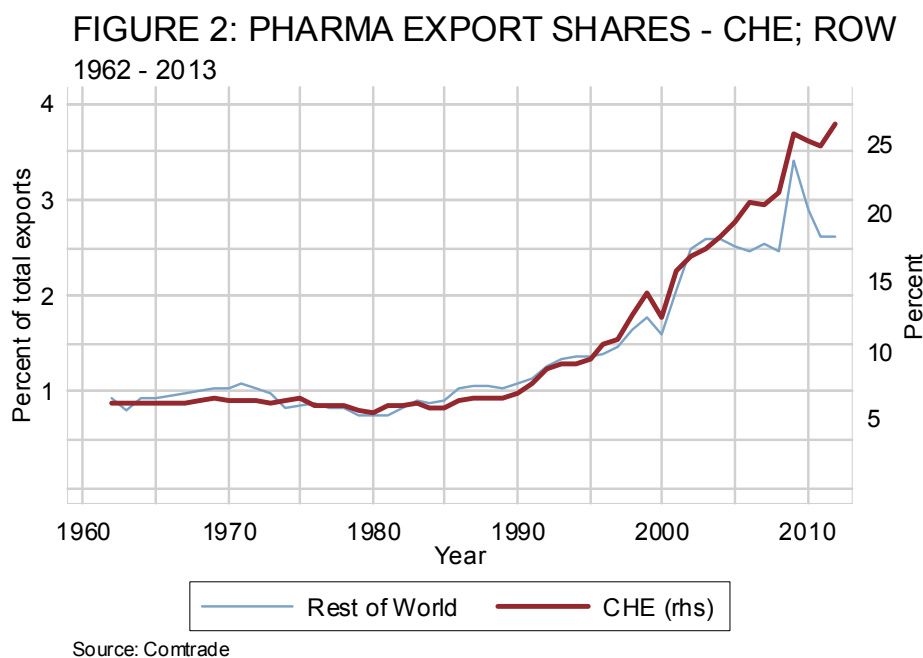
The model developed in the previous section is calibrated to the Swiss economy and its trade flows. The reason why Switzerland is a good example for the mechanism outlined in the theory is its strong comparative advantage in the pharmaceutical sector. This comparative advantage is documented by the fact that Swiss exports of pharmaceutical products exceed imports by a factor of approximately 3. Figure 1 below shows that, since the 1990s the levels of Swiss pharmaceutical imports and exports, measured as a share of Swiss GDP, increased continuously and in parallel.¹⁵ Throughout this period the ratio of exports and imports was roughly stable.



The remarkable increase in the importance of trade in pharmaceutical products for the Swiss economy, illustrated in Figure 1, also impacted the composition of Swiss exports. Thus, Figure 2 shows that pharmaceutical exports as a share of total exports (red line) has grown to constitute a dominant item of the Swiss export basket in recent years. In 2013, for example, Switzerland's pharmaceutical exports accounted for a share of 27.6 percent of total Swiss exports (USD 62.4 billion out of a total of USD 225.7 billion). Over the five years from 2009 to 2013, pharmaceutical products accounted for 26.0 percent of all Swiss exports. The figure also plots the

¹⁵Data are from comtrade.un.org; definitions based on SITC classification.

pharmaceutical export share for the rest of the world (blue line). While for Switzerland, this share increased by a factor of four between 1990 (6.8%) and 2013 (27.6%), the corresponding increase for the rest of the world was only slightly less pronounced, from 1.1 to 2.8 percent (i.e., by a factor of 2.6). Overall, the growth rates of pharmaceutical shares of Swiss trade and global trade was remarkably similar.



Figures 1 and 2 document a rapid increase in global trade of pharmaceutical products, which affected Switzerland's exports in particular due to the country's comparative advantage in the pharmaceutical sector. The impressive growth is likely to relate to demand factors. The World Bank reports that health expenditure in the three largest markets grew at an annual rate of 5.6% in the USA, 4.7% in the European Union and 4.1% in Japan between 1996 and 2012; these growth rates are far above the respective growth rates of per capita GDP during the same period (3.7%, 3.6% and 1.5%). Large parts of this growth were likely driven by per capita income and aging societies. Corresponding to the increase in global expenditure shares, trade volumes in pharmaceutical products have increased dramatically over the last few decades.

The sum of these observations makes Switzerland a paradigm of the theory developed above. Specifically, it shows that Switzerland has a strong

comparative advantage is the pharmaceutical sector, which is characterized by the two key characteristics of the model's *D*-sector.

Firstly, the pharmaceutical sector has shown impressive growth over recent years and decades – for Switzerland but also globally. Secondly, the production of pharmaceutical products is subject to large, up-front R&D costs. R&D costs for a new drug or compound range between USD 1 and 2 billion according to recent estimates¹⁶ and total R&D costs amount to up to a third of production costs and make the pharmaceutical industry one of the most prominent examples of R&D intensive industry.¹⁷ Moreover, the largest part of these costs accrue at early stages of basic research and in extensive clinical tests, i.e., substantially before the respective drug actually reaches the markets.¹⁸ In sum, R&D costs are exceptionally large and accrue long before operating profits accrue.

These observations make Switzerland a fitting example of country 1 of the theory: it has a comparative advantage in the pharmaceutical sector, which is characterized (i) by rapid demand growth and (ii) by large up-front R&D costs.¹⁹

3.2 Parametrization

3.2.1 The choice of periods

Before turning to the actual choice of the explicit model parameters, I need to specify which years correspond to the periods of the two-period model of Section 2. Specifically, the R&D and the production stage must be determined. Figure 1 above shows that, starting from 1990, there has been a gradual increase in the value of Swiss pharmaceutical exports as a share of GDP. Splitting the time line into an R&D phase and a period of physical production, which, respectively, correspond to period 1 and 2 in the model, is a non-obvious task. Clearly, mapping the stylized framework above to the data may be subject to judgemental errors.

For the sake of transparency, I base the choice of periods on two simple and intuitive criteria. The first criterion will determine the length of the

¹⁶DiMasi et al (2003) estimate that the costs of a marketable drug accrue to 0.8 billion 2000 US\$. Mestre-Ferrandiz et al (2012) report R&D costs of 1.9 billion in the 2000s per new medicine, up from 0.2 billion in the 1970s, both in 2011 US\$).

¹⁷See, e.g., Cohen and Klepper (1992) and Acemoglu et al (2004).

¹⁸See DiMasi et al (2003) and Deutsche Bank (2012), discussed below in more detail.

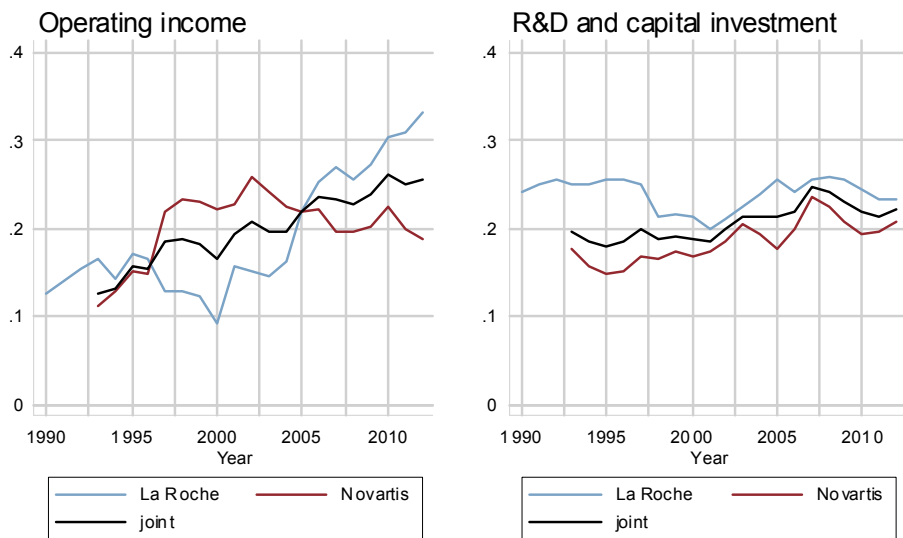
¹⁹See also Sauré (2015) for more information about Swiss trade and Switzerland's pharmaceutical sector.

periods. This length is equalized to the length of the pharmaceutical R&D process, which is taken from the literature. Second, the starting point and the ending point of the second period are determined by the largest increase in the Switzerland's export share of pharmaceuticals.

Regarding the first criterion, the R&D phase decomposes into one of basic research (drug discovery and pre-clinical tests) and one of clinical trials. The latter phase is reported to stretch over six or seven years. (DiMasi et al (2003) compute it to extend to 72.1 month, Deutsche Bank (2012) reports seven years.) The former phase is reported to be between 4.3 years (52.0 month in DiMasi et al 2003) to up to 8 years (Deutsche Bank 2012). These different estimates suggest that the R&D phase stretches over a time period between a decade and 15 years.²⁰ The fact that costs in the pre-clinical phase are considerably lower (DiMasi et al 2003 report a pre-clinical-to-total R&D expenditure ratio of 30%) reduces the effective, cost-weighted R&D period. I therefore opt for the lower range in the baseline scenario, fixing the length of the R&D period to one decade.

FIGURE 3: Profit and investment of Swiss pharma firms

Share of net income



Source: Datastream

The second criterion will fix the starting point and the ending point of the two 10-year periods on the time line. Specifically, I impose that the second period is defined through the largest increase of Swiss pharmaceutical

²⁰Acemoglu and Linn (2004) estimate that the first R&D activity takes place up to 20 years in anticipation of demand shocks.

exports. The maximum increase in Switzerland’s pharmaceutical exports, measured as a share of GDP, occurred at the end of the time-window, i.e. between the 10-year period of 1994-2003 and the period 2004-2013, when it increased by 4.39 percent from 3.77 to 8.17.²¹

Figure 3 presents investment and profits of Switzerland’s two largest pharmaceutical firms.²² The figure corroborates that the defined periods qualitatively correspond to the assumptions of the model. Specifically, the share of operating profits (or *operating income*, left panel) of both firms combined grew by 6.2 percent (from 16.9 to 23.1 percent). By comparison, the share of R&D and other investments (right panel) grew only moderately by 3.3 percent (from 19.0 to 22.3 percent).²³ These numbers suggest that the later period, 2004-2013, corresponds to a period, in which the gains from previous investments are reaped.

Lastly, to show that the R&D expenditure in the pharmaceutical sector matters for Switzerland’s economic aggregates, Figure 4 plots the R&D investments of the two Swiss pharmaceutical firms in percent of Swiss GDP (black line).²⁴ This share is slightly trending upwards, reflecting the growing importance of the pharmaceutical sector for the Swiss economy, and averages around 2.2 percent over the period 1994 to 2013.

The red line indicates Switzerland’s trade balance of goods, showing that both variables, pharmaceutical investments and the trade balance are of the same order of magnitude.²⁵ In accordance with the theory, the trade balance is negative in the first part of the time window (−0.49) and positive in the second half (+1.78). Notice that the two-period model predicts that pharmaceutical investment and R&D activity drops to zero in the second period, which is not the case in reality. Recall, however, that pharmaceutical

²¹Between the periods 1993-2002 and 2003-2012, that share increased by 4.31 percent and by less in all preceding, 10-year period sequences. Between 1984-1993 and 1994-2003 it increased by only 1.98 percent.

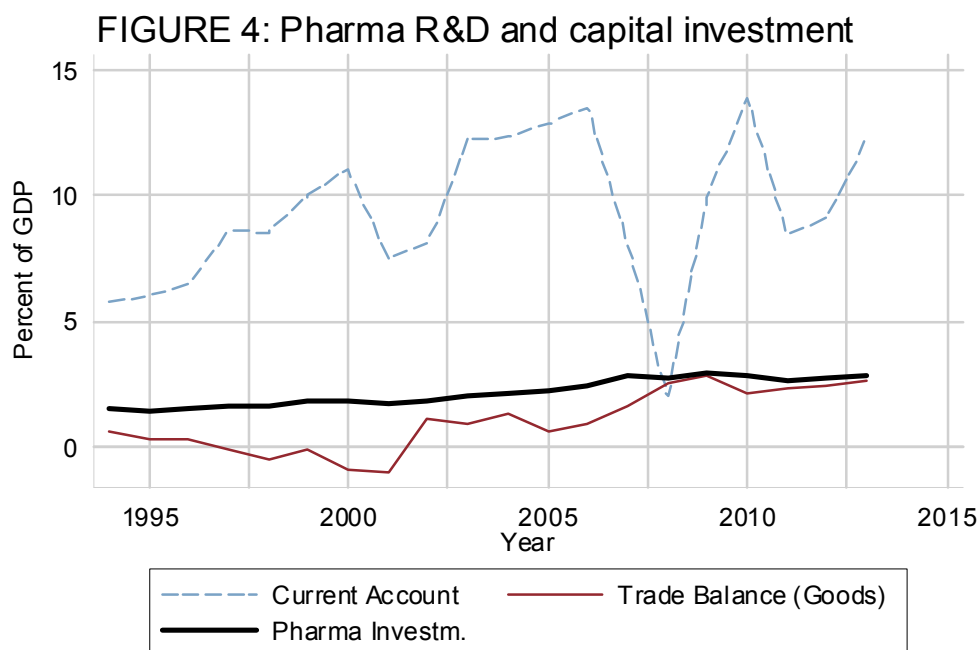
²²For Novartis, which was founded in 1996 through a merger of Ciba-Geigy and Sandoz, available data go back as far as 1993 but are not compiled for the time before then.

²³The left panel plots operating income (defined as the difference between sales and total operating expenses) as a fraction of net sales or revenues (defined as gross sales and other operating revenue less discounts, returns and allowances). The right panel plots R&D expenses (all direct and indirect costs related to the creation and development of new processes, techniques, applications and products with commercial possibilities) plus capital expenditure (all direct and indirect costs related to the creation and development of new processes, techniques, applications and products with commercial possibilities) as a fraction of net sales or revenues.

²⁴Recall that part of the pharmaceutical investment may be attributable to locations outside of Switzerland.

²⁵Trade in goods is measured according to BPM5 accounting standards.

R&D activity clearly drops relative to pharmaceutical operating profits, as indicated by Figure 3 above. In that sense, and in accordance with the theory, R&D investment dominates in the early period (1994-2003), whereas profits dominate in the second period (2003-2013).²⁶



Finally, the figure also plots the Swiss current account (CA - dashed blue line), which is larger than expenditure on pharmaceutical R&D by a factor of approximately four. Note that unlike what the theory predicts, the Swiss CA was in surplus for the entire period. This is a rather common feature of financial centers (see Lee et al 2008), and Switzerland’s current account surplus is to large extent driven by very volatile income on outbound FDI; thus, its dynamics should not be unduly related to the activities in the pharmaceutical sector specifically.

3.2.2 The choice of parameters

The next step consists of the actual choice of the vector of model parameters $(\varepsilon, \tau, \delta, \lambda, \alpha^C, \alpha^D)$. For the baseline specification, I set $\varepsilon = 1.85$, corresponding to the estimates for the Swiss economy presented in Auer and

²⁶Other components, like returns to FDI investment, have generated a Swiss current account surplus throughout the both periods. However, these dynamics do not disprove this paper’s general argument.

Sauré (2011).²⁷ The overall iceberg cost to 20% ($\tau = 1.2$) in the benchmark specification.²⁸ The relative size of the two countries is chosen so that the D -exporting country (Switzerland) is roughly 0.87 percent of the world economy ($\lambda = 114$).²⁹ Without loss of generality, the setup costs in the C -sector is normalized to unity ($\alpha^C = 1$).³⁰ The setup costs in the D -sector ($\alpha^D = \Omega\alpha^C = \Omega$) is calibrated so that the export basket of the D -exporting country equals 10.2 percent in period $t = 1$, reflecting the increase in the share of Swiss pharmaceutical exports between the two periods 1994-2003 and 2004-2013 (23.1 – 12.9). The discount factor is set to $\delta = 0.599$, thus applying a yearly discount factor of $\delta_{year} = 0.95$ to a time horizon of a decade. This assumption corresponds to assuming a ten-year period of R&D, followed by a ten year period of effective patent protection. I also consider alternative setups with combinations of $\varepsilon = 5$ (as suggested by trade models) $\tau = 1.74$ (as suggested by Anderson and van Wincoop (2004)) and $\delta = 1.04$ (reflecting a 20-year period of effective patent protection, where $\delta = \sum_{k=0}^9 \delta_{year}^k / \sum_{k=10}^{29} \delta_{year}^k$).

3.3 Calibration Results

As motivated above, the parameter Ω will be used to calibrate the model to generate an increase in country 1’s export share of 10.2 percent in the baseline specification. The variables of interest from the calibration exercise are

- $\Delta\omega$ – the change in country 1’s wage relative that of country 2, which coincides with the standard definition of the (change in) terms of trade. Additionally, because GDP is equal to the total wage bill, this number also reflects the differential in growth rates.

²⁷Auer and Sauré (2011) estimate the exchange rate elasticity of Swiss exports, measured in values, to be -0.85 . Hence, the elasticity of quantities, defined in the model as ε , satisfies $-0.85 = -p * d \ln(pq) / dp = -1 - p * d \ln(q) / dp = -1 - \varepsilon$. This specification is on the lower end of the range of elasticities usually adopted (see, e.g., Corsetti et al 2013); I therefore also experiment with higher values.

²⁸Although specific subcomponents of trade costs have been estimated based on Swiss data (e.g., Egger and Lassmann 2015 and Kropf and Sauré 2014), no estimate of overall trade costs exists.

²⁹According to the World Development Indicators, the Swiss GDP was at 650 billion US\$ in 2013, and the World output was at 74 910 billion US\$.

³⁰This normalization impacts the equilibrium mass of active firms but none of the other variables.

- ΔRER_1 – the change in country 1’s real exchange rate between period 0 and period 1, defined as the (change in) price-adjusted relative wages.
- $NX_{1,t} = CF_{1,t}$ – the GDP-normalized net exports or capital outflows of country 1 in period t .

The calibration results of the various specifications are displayed in Table 1, with the baseline specification in the first column and data in the last two columns. An initial observation is in order before turning to the endogenous variables: the parameter Ω is always smaller than δ (as required by condition (18)) but very close to δ . In particular, Ω never falls short of δ by more than 1/8 of a percent. The reason for this fact lies in the size of country 1 (i.e., Switzerland). Because, in this model, country 1 supplies the world demand of the D -type good in period $t = 1$, it will completely specialize in D -production whenever the D -technology allows for an efficient production of D -goods (i.e., if $\Omega = \alpha^D/\alpha^C$ is very small). However, because the targeted share of D -type goods in period $t = 1$ is smaller than unity, this condition imposes a rather strict lower bound of the choice of parameter Ω .

Table 1: Calibration Results with D-export share = 10.2

Model									Data	
	$\delta=0.599$				$\delta=1.045$				1994-2003 to 2004-2013	1994 to 2013
	$\tau=1.2$		$\tau=1.74$		$\tau=1.2$		$\tau=1.74$			
	$\varepsilon=2$	$\varepsilon=5$	$\varepsilon=2$	$\varepsilon=5$	$\varepsilon=2$	$\varepsilon=5$	$\varepsilon=2$	$\varepsilon=5$		
Parameter [%]										
$\Omega/\delta-1$	-0.082	-0.033	-0.098	-0.045	-0.104	-0.043	-0.125	-0.057		
Endogenous Variables [%]										
$\Delta\omega$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.034	19.832
ΔRER	0.025	0.006	0.066	0.011	0.032	0.008	0.084	0.014	1.724	14.369
NE_{10}/GDP_{10}	-2.928	-1.194	-2.870	-1.175	-4.982	-2.062	-4.856	-2.024	0.356	-2.351
NE_{11}/GDP_{11}	5.323	2.062	5.313	2.054	5.323	2.062	5.313	2.054	3.010	3.934

Note: the equations determining the equilibrium are (21), (22), (26) and (27). In all specifications, $\lambda=114$ according to the Swiss economic size and $\alpha^C=1$. Ω is chosen so that the share of D-exports is 10.2 in period $t=1$.

The first variable of interest, the countries’ relative wages (or terms of trade), shows virtually no reaction to trade flows, the expansion of country 1’s exports between period 0 and period 1. This result may appear natural

under very small trade costs. Indeed, it can be shown that the equilibrium relative wages are unity ($\omega_t = 1$) under zero trade costs ($\tau = 1$).³¹ However, the result also holds under sizable trade costs ($\tau = 1.74$). The following two forces that affect the wages almost cancel out. First, country 1's relative wage tends to fall because the capital outflows, through which foreign investors collect the interest on their investments, generate a depreciation of the terms of trade. This effect was labeled by Keynes the *secondary burden* of international transfers (see Corsetti et al 2013). Second, there is the home market effect, which implies that the growth of tradable goods between the first and the second period generates an appreciation of country 1's terms of trade, which counteracts the *secondary burden*. It turns out that both effects almost cancel out so that the change in relative wages is negligible. (It is worth noting, however, that for small λ and for large τ this statement no longer holds.)

Second, country 1's real exchange rate appreciates, but rather moderately so – by approximately one quarter of a percent in the set of eight specifications. These effects are due to the expansion in the set of varieties produced in country 1 in combination with the trade costs that drive a wedge between the local prices and the foreign prices. Accordingly, the effect on the *RER* is larger when trade costs are higher (a standard feature of Krugman's (1980) new trade model).

The first calibration result is a strong persistence of the terms of trade (real exchange rate adjusted wage ratios) and the real exchange rate. These results do not match the rather large changes in both of these variables, reported in the last two columns of Table 1.³² However, this discrepancy should not be interpreted as a failure of the model. Indeed, for a small open economy with a large financial sector, the real exchange rate can be expected to be driven or predicted not by trade volumes but by international capital flows, which are not directly related to export and import flows.³³ Instead, the calibration shows that the changes in trade flows contributed very little (if at all) to the recent appreciation of the Swiss franc and to the

³¹See Appendix.

³²The change of relative wage ratio reported in Table 1 is computed based on Swiss and the German real wage indices, expressed in one common currency. Data sources are the Swiss *Bundesamt für Statistik* and the IFS. The change in the RER is based on the Swiss real exchange rate, narrow definition, as reported by the BIS.

³³This statement is particularly obvious in the period of the financial crisis, when financial flows to heaven currencies and the unwinding of carry trades appeared to be dominant effects shaping the valuation of the Swiss currency (see, e.g., IMF 2013 and 2014). Accordingly, strong (real and nominal) appreciations of the Swiss franc have occurred since 2007.

improvement of Switzerland's terms of trade.

The third and final variable of interest is the net export share. It turns out that the average net exports of the periods 1994–2003 were positive. Instead of looking levels, I therefore focus on the increase of GDP-normalized net exports (2.65 percent of GDP in the data; see last two rows in the penultimate column of Table 1) as a metric to assess the performance and success of the model. In the baseline model, reported in the first column of the table, this increase is over-predicted by a factor of roughly 3. When the elasticity of substitution is changed from $\varepsilon = 1.85$ to $\varepsilon = 5$ (as typically specified in calibrations of trade models), the increase in net exports ($2.02 - (-1.17) = 3.2$ percent of GDP) is well matched (second column), exceeding the increase in the data by as much as 20%. These numbers remain almost unchanged, when assuming relatively high ad valorem trade costs of 74 percent.

Table 2: Calibration Results with D-export share = 10.2; $\lambda=5$

Model								
	$\delta=0.599$				$\delta=1.045$			
	$\tau=1.2$		$\tau=1.74$		$\tau=1.2$		$\tau=1.74$	
	$\varepsilon=2$	$\varepsilon=5$	$\varepsilon=2$	$\varepsilon=5$	$\varepsilon=2$	$\varepsilon=5$	$\varepsilon=2$	$\varepsilon=5$
Parameter [%]								
$\Omega/\delta-1$	-0.082	-0.033	-0.098	-0.045	-0.104	-0.043	-0.125	-0.057
Endogenous Variables [%]								
$\Delta\omega$	0.010	0.016	0.080	0.058	0.013	0.020	0.102	0.074
ΔRER	0.405	0.113	1.095	0.195	0.518	0.144	1.401	0.250
NE_{10}/GDP_{10}	-2.434	-0.981	-2.313	-0.907	-4.142	-1.695	-3.913	-1.561
NE_{11}/GDP_{11}	4.426	1.694	4.282	1.585	4.426	1.694	4.282	1.585

Note: the equations determining the equilibrium are (21), (22), (26) and (27). In all specifications, $\lambda=5$ and $\alpha^C=1$. Ω is chosen so that the share of D-exports is 10.2 in period $t=1$.

Additionally, one may compare the value of export predicted by the calibration to the net exports of the ending point of the ten-year periods considered, i.e., to the values in 1993 and 2013. The according data are reported in the last column of the table. The according increase in the data

is 6.29 percent of GDP, a number that the calibrated model underpredicts by 49 percent (at $(\delta, \tau, \varepsilon) = (0.599, 1.74, 5)$) or overpredicts by 64 percent (at $(\delta, \tau, \varepsilon) = (1.045, 1.2, 2)$).

Overall, however, it seems that the calibration to reasonable parameters tends to overpredict the increase in Switzerland's net exports. A reason for this discrepancy might be the real appreciations of the Swiss currency (driven, as argued above, by independent financial flows). These parts of the appreciations, exogenous to the trade dynamics, might have dampened the increase in the Swiss net exports.

The general picture is preserved when calibrating the model to a similar increase of trade in R&D-intensive goods in a country of much larger dimensions. Table 2 reports the corresponding calibration results, which show that neither the terms of trade nor the real exchange rate exhibit strong movements. Even under large trade costs, the terms of trade barely increase by more than a tenth of a percent, and the real exchange rate increases by less than 1.5 percent.³⁴ At the same time, the sizable net exports are of the same order of magnitude as those reported in Table 1.³⁵

4 Conclusion

This paper has proposed a novel mechanism by which global imbalances arise. It has shown that countries with a comparative advantage in a sector that is characterized by fast growth and large up-front R&D costs can experience substantial capital inflows and outflows. These capital flows (and the trade deficits and surpluses that accompany them) occur under relatively stable terms of trade and real exchange rates. Additionally, given that trade costs are moderate, the cross-country differences in savings rates and income growth – variables that are usually cited to explain and rationalize global imbalances – are negligible. The dynamics of Swiss net exports and the increased share of pharmaceutical products in the Swiss export basket are argued to exemplify the mechanism described by the theory. A calibration exercise for the increase in pharmaceutical trade matches the increase in Switzerland's net exports reasonably well.

³⁴Recall that zero trade costs imply no movements at all.

³⁵For equally sized countries ($\lambda = 1$), the terms of trade (real exchange rate) increase by less than 1.2 (2.7) percent.

A Appendix

A1. Proofs

Proof of (13). The expression for expenditure is

$$\begin{aligned}
 e_{i,t} &= P_{i,t}C_{ii,t} + \tau P_{j,t}C_{ij,t} \\
 &= \tau P_{j,t}C_{ij,t} \left(\left(\frac{P_{i,t}}{\tau P_{j,t}} \right)^{1-\varepsilon} + 1 \right) \\
 &= \tau P_{j,t}C_{ij,t} \left(\left(\frac{w_{i,t}}{\tau w_{j,t}} \right)^{1-\varepsilon} \frac{n_{it}}{n_{jt}} + 1 \right)
 \end{aligned}$$

where (12) has been used in the first step and (10) in the second.

Proof that $\tau = 1$ implies $\omega_t = 1$. The crucial conditions are given by the system (21) and (22) and (26) and (27). In the case of zero trade costs, ($\tau = 1$) and normalized nominal rate of return ($R = 1$), the system (21) and (22) becomes

$$\begin{aligned}
 \left(\lambda \frac{\omega_0 + \Omega \omega_1}{(\omega_0)^{1-\varepsilon} \frac{n_{2,0}}{n_{1,0}} + 1} - \frac{1 + \Omega}{\left(\frac{1}{\omega_0} \right)^{1-\varepsilon} \frac{n_{1,0}}{n_{2,0}} + 1} \right) &= -\lambda (\delta \omega_0 - \Omega \omega_1) \\
 \lambda \frac{\omega_0 + \Omega \omega_1}{(\omega_1)^{1-\varepsilon} \frac{n_{2,1}}{n_{1,1}} + 1} - \frac{1 + \Omega}{\left(\frac{1}{\omega_1} \right)^{1-\varepsilon} \frac{n_{1,1}}{n_{2,1}} + 1} &= \frac{\lambda}{\delta} (\delta \omega_0 - \Omega \omega_1)
 \end{aligned}$$

Guessing $\omega_t = 1$, this is

$$\begin{aligned}
 \frac{1 + \Omega}{\frac{n_{2,0}}{n_{1,0}} + 1} \left(\lambda - \frac{n_{2,0}}{n_{1,0}} \right) &= -\lambda (\delta - \Omega) \\
 \frac{1 + \Omega}{\frac{n_{2,1}}{n_{1,1}} + 1} \left(\lambda - \frac{n_{2,1}}{n_{1,1}} \right) &= \frac{\lambda}{\delta} (\delta - \Omega)
 \end{aligned}$$

which can be rearranged as

$$\begin{aligned}
 (1 + \Omega) \left(\lambda - \frac{n_{2,0}}{n_{1,0}} \right) &= -\lambda (\delta - \Omega) \left(\frac{n_{2,0}}{n_{1,0}} + 1 \right) \\
 (1 + \Omega) \left(\lambda - \frac{n_{2,1}}{n_{1,1}} \right) &= \frac{\lambda}{\delta} (\delta - \Omega) \left(\frac{n_{2,1}}{n_{1,1}} + 1 \right)
 \end{aligned}$$

or

$$(1 + \delta) \lambda = [(1 + \Omega) - \lambda(\delta - \Omega)] \frac{n_{2,0}}{n_{1,0}}$$

$$\Omega(\delta + 1) \lambda = [\lambda(\delta - \Omega) + \delta(1 + \Omega)] \frac{n_{2,1}}{n_{1,1}}$$

It can be readily checked that this system is equivalent to (26) and (27) under $R = \omega_t = 1$. Hence, the initial guess $R = \omega_t = 1$ is verified.

A2. Tables

Table A1: Calibration Results with D-export share = 27.6

Model									Data	
	$\delta=0.599$				$\delta=1.045$				1994-2003 to 2004-2013	1994 to 2013
	$\tau=1.2$		$\tau=1.74$		$\tau=1.2$		$\tau=1.74$			
	$\varepsilon=2$	$\varepsilon=5$	$\varepsilon=2$	$\varepsilon=5$	$\varepsilon=2$	$\varepsilon=5$	$\varepsilon=2$	$\varepsilon=5$		
Parameter [%]										
$\Omega/\delta-1$	-0.243	-0.094	-0.292	-0.126	-0.310	-0.120	-0.373	-0.161		
Endogenous Variables [%]										
$\Delta\omega$	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	9.034	19.832
ΔRER	0.074	0.018	0.195	0.031	0.095	0.023	0.250	0.040	1.724	14.369
NE_{10}/GDP_{10}	-7.192	-3.140	-6.716	-3.018	-11.429	-5.319	-10.376	-5.055	0.356	-2.351
NE_{11}/GDP_{11}	15.857	5.784	15.826	5.764	15.857	5.784	15.826	5.764	3.010	3.934

Note: the equations determining the equilibrium are (21), (22), (26) and (27). In all specification, $\lambda=114$ according to the Swiss economic size and $\alpha^C=1$. Ω is chosen so that the share of D-exports is 27.6 in period $t=1$.

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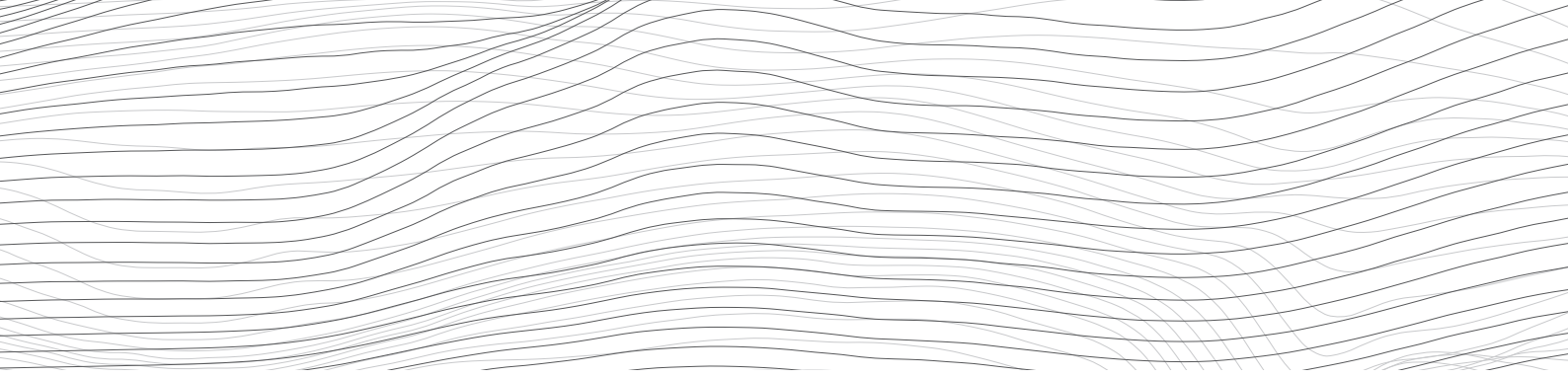
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