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Diffusion and directed technological knowledge, human capital and wages

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By connecting the North–South diffusion and the bias of non-scale technological knowledge and by considering endogenous human capital, we relate the technological-knowledge diffusion with levels, inter-country gaps, growth rates, wage-inequality paths and specialisation patterns. Inter-country gaps fall towards the steady state and the South produces more final goods at the end of the adjustment process. Moreover, it exports relatively more final goods of the type that uses more intensively the relatively abundant human capital and imitated intermediate goods. However, outputs, wages and prices remain different and differences in prices originate the intra-country wage-inequality paths observed in developed and developing countries, since the early 1980s.

1. Introduction

Overall, empirical evidence detects, in developed (North) and developing (South) countries, strong technological-knowledge progress, a rise in the proportion of skilled labour, a rise in wage inequality in favour of skilled labour and enlarged international-trade flows, since the early 1980s (e.g., Acemoglu, 2003; Avalos and Savvides, 2006; Berman et al., 1998; Coe and Helpman, 1995; Machin and Van Reenen, 1998; Robertson, 2004; Zhu and Trefler, 2005). The aim of this paper is to develop an endogenous growth model consistent with these facts.

We follow and contribute to two main lines of research: technological-knowledge diffusion growth models (e.g., Grossman and Helpman, 1991); and wage-inequality growth models (e.g., Acemoglu and Zilibotti, 2001). Neither the former nor the latter models attest to all the above trends. The former models ignore wage-inequality analysis. The latter models tend to exclude international technological-knowledge diffusion, are dominated by labour levels and comprise two rival approaches (e.g., Zeira, 2007): (i) the trade approach, anchored in the Stolper–Samuelson theorem (e.g., Leamer, 1998; Wood, 1995a, b), predicts, however, a rise in relative unskilled wage in developing unskilled abundant countries;[1] (ii) the skill-biased technological change (SBTC) approach, rooted in the market-size effect on the technological-knowledge bias that drives wages (e.g., Acemoglu, 2002), predicts, in turn, a rise in relative unskilled technological knowledge and thus in relative unskilled wage in skilled abundant developed countries due to enlarged trade with developing ones.

The international technological-knowledge diffusion through trade allows us to connect the two wage-inequality approaches, as is empirically suggested (e.g., Jaumotte et al., 2009).

We assume that the North is more productive due to better institutions, higher human capital and innovative R&D (e.g., Aghion and Howitt, 1992). Southern R&D results are imitations of innovations and it has a marginal cost advantage in production (e.g., Grossman and Helpman, 1991). Thus, the South imports intermediate goods, where R&D is applied, that have not yet been imitated and exports those previously imitated;[2] i.e., intermediate goods are the vehicle of technological-knowledge diffusion. In line with Mincer (1993) and Lucas (1993), the time spent accumulating human capital is split between school and on-the-job-training (OJT). Relative to skilled human capital, unskilled human capital is OJT intensive and is less productive. The two types of human capital, due to different intensities in the two formation inputs, clearly distinguish two technologies in competitive final goods production.

Each type of human capital uses specific quality-adjusted intermediate goods. Thus, in line with the SBTC literature, the substitutability between technologies together with the complementarity between inputs allows us to unde7rstand the path of technological-knowledge bias. By

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[1] Accordingly, recent theoretical and empirical studies try to rethink the trade effects on wages (e.g., Broda and Romalis, 2009; Burstein and Vogel, 2009; Egger and Kreickemeier, 2009; Krugman, 2008; Verhoogen, 2008).

[2] Thus, countries have access to the same technological knowledge, by either domestic production or imports.

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removing (market) scale effects, as recommended by the dominant literature on scale effects (e.g., Jones, 1995a, b), the technological-knowledge bias is affected by prices, since more expensive goods create higher profits for producers. Therefore, due to technological-knowledge diffusion under trade, when the skilled abundant North exports inputs incorporating its R&D results to an unskilled abundant South, it benefits from the higher prices of goods produced by Southern skilled human capital. The profit opportunities redirect R&D towards inputs that increase the marginal productivity and thus the wage of skilled human capital in the North and, due to technological-knowledge diffusion, in the South.

By considering endogenous human capital, economic growth ceases to be only driven by technological-knowledge progress. Moreover, the skill-premium per worker (i.e., the relative wage of workers who accumulate skilled human capital) can rise even when the skill-premium per unit of human capital (i.e., the relative wage of skilled human capital) falls, due to the relative rise in skilled human capital per worker. Furthermore, human-capital accumulation affects the dynamic inter-country specialisation pattern.

In trade-theory tradition, there are neither North–South movements of workers nor North–South movements of firms; i.e., wages and interest rates are domestically found. We also assume that trade is always balanced. The pattern of final-goods specialisation is decided by the relative endogenous productivity of each country in each good, which is affected by the path of human capital and quality-adjusted intermediate goods. In the spirit of Vernon (1966), the pattern of intermediate-goods trade is determined by innovative and imitative activities.

While before trade the technological knowledge available to the South is domestic, under trade the top quality intermediate goods available internationally embody the North's technological knowledge, which is a static trade benefit to the South. Thus, under trade, inter-country differences in human-capital levels and institutions impose different inter-country prices.[3] The higher prices of final goods produced by skilled human capital in the unskilled abundant South redirect R&D towards the complementary intermediate goods — i.e., increase the relative demand for skilled-specific new designs — which boost the relative worldwide supply of skilled-specific intermediate goods and thus the skill premium in both countries.

Indeed, as the North–South average relative price of final goods produced by skilled human capital (the one that is relevant under trade) is always higher than the one in the pre-trade North, international trade redirects technological knowledge in favour of intermediate goods used by skilled workers, which relatively boosts their wages in both countries. That is, the path of wages is driven by the operation of the price channel under trade, which engenders more moderate paths for technological-knowledge bias. As a result, the initial Southern level effect, induced by access to top quality intermediate goods, is reverted and the wage-inequality path is milder than in the pre-trade North.

Both countries produce, consume and export both types of final goods, since they always possess both types of human capital. The South, which in addition to the level effect also benefits from growth effects, produces more final goods at the end of the adjustment process, since inter-country human-capital and technological-knowledge gaps fall; it exports relatively more final goods of the type that use the relatively abundant human capital more intensively — in line with the Hechscher–Ohlian model. However, inter-country differences in the quality of institutions — i.e., in exogenous productivity — and in human-capital levels always impose lower output and lower wages in the South. Moreover, in line with the Ricardian model, the South produces, consumes and exports imitated intermediate goods.

To sum up, a model has been developed, which, for the first time in the literature, combines technological-knowledge diffusion under trade, technological-knowledge bias driven by the price channel and human-capital accumulation in order to generate predictions compatible with all the above-mentioned facts.

In Section 2, the paper proceeds to characterise both economies and the international market. In Section 3 we derive the dynamic general equilibrium, we obtain the level, steady-state and transitional-dynamics effects, and we analyse the comparative statics and dynamics resulting from alternative parameters. In Section 4 we present some concluding remarks.

2. Economic structure

By expanding the closed-economy endogenous R&D-growth model with fixed labour levels in Afonso (2008), we define the productive setup, which, excluding some parameter values and R&D activities, is common to both countries. Each economy is populated by infinitely-lived individuals and population growth is zero. Individuals choose between consumption and savings on income allocation, and between production and human-capital accumulation on time allocation. Competitive final goods use unskilled, L, or skilled, H, human capital with L- or H-specific quality-adjusted intermediate goods, which are produced under monopolistic competition by joining units of aggregate output and designs (e.g., Aghion and Howitt, 1992). Designs are obtained through innovative and imitative R&D.

2.1. Individuals

A time-invariant number of heterogeneous individuals decide income and time allocation. Income is partly spent on consumption, C, of aggregate final output, Y, and partly lent in return for future interest. Time, t, is divided between human-capital accumulation, and working to earn a share of Y proportional to the individual's human capital. Heterogeneity is arrested by the type of human capital accumulated, $m = L, H$.

The lifetime utility function $\int_0^\infty \frac{C(t)^{1-\theta}-1}{1-\theta}\exp(-\rho t)dt$, where $\rho > 0$ is the subjective discount rate and $\theta > 0$ is the relative risk aversion, states individuals (identical) preferences. Savings are the accumulation of financial assets, K, which have return — the interest rate, r, that, due to arbitrage in the domestic assets markets, only relies on t. Lending takes the form of ownership of profitable firms (those producing intermediate goods). The value of these firms, in turn, is the value of patents. The budget constraint equalises savings plus consumption to income earned at t: $\dot{K}(t) + C(t) = r(t)K(t) + \sum_{m=L,H}[1-u_{F,m}(t)-u_{T,m}(t)]w(t)m(t)$, where $w_m(t)$ is the wage per unit of m at t; $u_{F,m}(t)$ and $u_{T,m}(t)$ are the fractions of t spent by m, respectively, at school and OJT — thus, OJT is costly, in the sense that it requires time away from work (e.g., Mincer, 1993).

Individuals accumulate either H or L using schooling and OJT. As in Lucas (1988), the productivity of the time spent increases with the individual's human capital. A constant elasticity of substitution (CES) accumulation function is considered

$$\frac{\dot{m}(t)}{m(t)} = \left[\varphi_m\left(\underbrace{\chi_F u_{F,m}(t)}_{School_m(t)}\right)^{\phi} + (1-\varphi_m)\left(\underbrace{\chi_T u_{T,m}(t)}_{OJT_m(t)}\right)^{\phi}\right]^{1/\phi} - \delta_m, \qquad (1)$$

where δ_m is the depreciation rate of m; terms within square brackets are schooling and OJT inputs; χ_F and χ_T are efficiency parameters assessing schooling and OJT productivities (we assume that $\chi_F \ge \chi_T \ge \delta_m$, otherwise m falls). $\varphi_m \in [0, 1]$ is the intensity parameter, which determines the relative weight of the two inputs, and we consider that $\varphi_H > \varphi_L$, such that H is school intensive. Assuming that H is more productive, the idea is that schooling provides wide and flexible human capital, while OJT provides more specific skills (e.g., Mincer, 1993); from Eq. (1), schooling and OJT can be either complements or substitutes, relying

[3] The path of prices is empirically supported by studies, such as Krueger (1997) and Broda and Romalis (2009).