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Technological change, human capital, and absorptive capacity: Can Turkey escape the Middle Income Trap?

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Abstract

In this study, we build an endogenous growth model around the idea that in order to escape the Middle Income Trap (MIT) and catch-up with the rich economies, a country in the MIT (like Turkey) needs to experience technological change at a rate faster than that of the world frontier technological progress, and to realize convergence, she must increase technological absorptive capacity. We show that by increasing the years of schooling, educational quality, and the share of capital goods imports in GDP, not only the level of technology will improve, but also the rate of technological progress and labor productivity growth will improve, making it possible for Turkey to eventually escape the trap. Moreover, increasing the share of researchers in overall educated population helps to avoid the trap by decreasing the threshold to start the catch-up process, and increasing the domestic technology level relative to the world frontier.

Key words: Economic growth, productivity, structural change, middle income trap.

JEL codes: O11, O40, O47.

1. Introduction

Middle Income Trap (MIT) usually refers to the inability of a middle income country to graduate to the group of high income countries. MIT countries are the ones which were able to surpass low income levels, and have made significant advances in social and economic areas, but couldn't reach the socioeconomic ranks attained by high income countries. Non-Middle Income Trap (NMIT) countries are the ones which have made it from middle income to high income country category successfully.[1] The MIT is the main challenge for developing countries, and the related literature emphasizes the role of "structural transformation" and "human capital" to overcome the MIT through accumulating capabilities and increasing innovative productive capacity.[2]

In this study, our objective is to develop and quantitatively analyze an endogenous growth model for Turkey by drawing attention to the Middle Income Trap literature. First, using a basic shift share analysis,we try to assess the relative importance of "human capital" and "structural transformation" related factors of being stuck in the MIT, and then we develop the theoretical model by referring to our findings from the shift share analysis.

Findings from the shift share analysis show that average labor productivity growth rates differ significantly across MIT and NMIT countries. In the shift share analysis, average labor productivity growth is broken down into two components, specifically 'within-sector' productivity growth, and 'across-sector' productivity growth, which emerges due to structural transformation. Similar to our findings for a typical MIT country, employing shift share analysis for Turkey shows that her low productivity performance stems from poor within-sector productivity gains. Consequently, in relation to the ability to escape the MIT, our theoretical model focuses on the factors which can be associated with technological progress leading to within-sector productivity gains, rather than with structural transformation.

The theoretical model is constructed around the idea that in order to escape the MIT and initiate catch-up with the high income economies, a country in the MIT (like Turkey) needs to experience domestic technological change at a rate faster than that of the countries out of the MIT. For a relatively backward economy, technological change is possible through imitation or the absorption of world technology (i.e., technology transfer), and/or domestic innovation efforts. Both require sufficient, or a threshold level of human capital (Borensztein et al., 1998; Xu, 2000), which depends on the schooling rate as well as the quality of education

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1 There is no consensus on whether middle income trap exists or not in the literature. For instance, Prichett and Summers (2014) argue that middle income trap is a questionable qualification for the growth theory. They argue that there is convincing evidence for regression to the mean in economic growth process, i.e. growth rates reverting to their means. However, we don't argue whether the trap exists or not in this study. We analyse the issue by focusing on the literature that supports the argument of the presence of the MITs.

2 Although it is not easy to differentiate between these two issues from each other when we consider high interactions among them, we see that some studies put higher emphasis on the "human capital" issue (for example Eichengreen et al., 2013; Jimenez et al., 2012; Jankowska et al., 2012), and others focus on "structural transformation" related issues (for example Abdon et al., 2012; Felipe, 2012; Kharas and Kohli, 2011) especially.

(Hanushek and Woessmann, 2010, 2012). Technology transfer may occur through the purchase of patents, FDI, and/or import of capital goods; and the extent to which foreign technology is absorbed in the domestic economy will depend on the available human capital (Nelson and Phelps, 1966; Benhabib and Spiegel, 1994; Coe and Helpman, 1995; Del Barrio-Castro et al., 2002; Engelbrecht, 1997; Falvey et al., 2007; Seck, 2012; Teixeira and Fortuna, 2010).

The rest of the paper is organized as follows. Section 2 introduces the shift share analysis and presents findings for typical MIT and NMIT countries and Turkey. Section 3 introduces the theoretical model. In section 4, using some computed and assumed parameter values for the Turkish economy, we quantitatively evaluate the model under baseline parameter values, and under various scenarios. Section 5 concludes.

2. MIT and the shift share analysis

In the literature, there are mainly two distinct approaches to evaluate the existence of the Middle Income Trap. According to the first approach, the MIT can be considered as the existence of a weak or stagnating growth performance in absolute per capita income levels (Eichengreen et al., 2013; Abdon et al., 2012 and Aiyar et al., 2013); the second approach considers the MIT as unsatisfactory relative convergence of per capita income levels to those of the rich economies (Woo, 2012; Robertson and Ye, 2013).

In the MIT literature, certain East Asian countries, i.e. South Korea, Taiwan, Hong Kong, Singapore, and Japan, some European countries such as Spain, Portugal, Finland, and Greece, and finally Israel from the Middle East are considered to be success stories in escaping the MIT. Conversely, Turkey, along with some Latin American economies of Chile, Colombia, Mexico, Argentina, Venezuela, and Brazil, as well as a couple of Southeastern Asian economies, namely Malaysia and Indonesia are said to be stuck in the MIT.

In our study, we categorize the MIT countries by the criterion suggested by Robertson and Ye (2013). The authors claim that countries with 8%-36% of U.S. per capita GDP (PPP-adjusted, 2005 constant prices) could be in the MIT, and exhibit unsatisfactory relative convergence in per capita income levels to those of the rich economies[3]. Based on Roberstson and Ye (2013), we determine that a

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[3] We think that their approach has some advantages. For instance, they utilize an econometric approach instead of ad hoc definitions to determine the MIT countries; and their approach enables us to discriminate between middle income traps and other short run developments. Moreover their findings on which countries are trapped are consistent with other results in the literature (Abdon et al., 2012; Aiyar et al., 2013; Eichengreen et al., 2013 and Woo, 2012).

country is stuck in the MIT if she has 8%-36% of the U.S. per capita GDP in 1960 and 2010.[4,5]

In the present section of the study, we try to understand the relative importance of "human capital" and "structural transformation" related factors of labor productivity growth for typical MIT and NMIT countries. Instead of focusing on any specific country, we would like to investigate how productivity and its determinants evolve in average MIT and NMIT countries.[6]

In order to evaluate the relative significance of "structural transformation" versus "human capital" factors of being stuck in the MIT, we decompose the determinants of labor productivity growth via shift share analysis. The shift share literature claims that aggregate labor productivity growth may originate from reallocation of employment across sectors (static and dynamic structural change (SC) productivity improvements), and also may be due to advances in labor productivity within each sector (Pieper, 2000; Roncolato and Kucera, 2014; McMillan and Rodrik, 2011; de Vries et al., 2013). Our decomposition analysis follows de Vries et al. (2013) and we decompose labor productivity growth into "within-sector productivity growth", "static structural change productivity growth" and "dynamic structural change productivity growth" components.

de Vries et al. (2013) claim that the pattern of aggregate labor productivity (LP) growth can be explained by employing the following decomposition[7]:

$$\Delta AP_t = \sum_i \varphi_{i,t-k}\, \Delta SP_{i,t} + \sum_i SP_{i,t-k}\, \Delta\varphi_{i,t} + \sum_i \Delta\varphi_{i,t}\, \Delta SP_{i,t} \quad (1)$$

In this decomposition, AP_t represents aggregate (economy-wide) productivity level, and $SP_{i,t}$ demonstrates labor productivity level of sector-i at time *t*. Labor productivity is calculated by dividing aggregate and each sector's real output by its corresponding employment figure. Employment share of a sector-i is the ratio of sector-i's employment to overall employment, and $\varphi_{i,t}$ stands for employment share of sector-i at time *t*. Change in the level of each variable is shown by the Δ operator.

In the decomposition equation (1), the first term is the "within-sector" component that consists of the weighted sum of productivity growth within each sector (the weights are the employment share of each sector at the beginning of the

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4 For further details: please see Yılmaz (2015a).

5 By using Heston et al. (2012), we determine that NMIT countries are Cyprus, Greece, Portugal, Hong Kong, Japan, South Korea, Singapore and Taiwan, and MIT countries consist of Algeria, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Fiji, Gabon, Guatemala, Honduras, Iran, Jordan, Malaysia, Mauritius, Mexico, Namibia, Panama, Paraguay, Peru, the Philippines, Romania, South Africa, Syria, Turkey and Uruguay.

6 In the study, typical and representative implies unweighted country average for both relevant country groups.

7 We prefer decomposition equation (1) since it covers dynamic structural change productivity gains. However, various decomposition equations yield similar results (Yılmaz, 2015b).

period). The second term measures whether workers move to above-average productivity level sectors (static structural change effect) and the third term shows the combined effect of changes in employment shares and changes in sectoral productivity levels (dynamic structural change effect). Static structural change effect exhibits the capability of a country to move labor from low productivity activities to high productivity ones and dynamic structural change effect demonstrates the potential of a country to reallocate its labor towards industries with high productivity growth (Fagerberg, 2000).

To examine the relative importance of the MIT determinants, we employ equation (1) with Groningen Growth and Development Center (GGDC) database that includes annual employment and real value added statistics for 28 countries with 10 sectors for 1950-2005. Since we deal with labor productivity developments in the MIT and NMIT countries, among these 28 countries, we analyse 13 countries that can be categorized as a MIT or a NMIT country.[8] These countries are Japan, South Korea, Singapore and Taiwan for the NMIT country group; and Bolivia, Brazil, Chile, Colombia, Costa Rica, Malaysia, Mexico, Peru, the Philippines for the MIT country group.

The database does not include data from Turkey. In that respect, we have two options: either exclude Turkey and analyze labor productivity developments in a representative (typical or average) MIT country by considering only the available countries, or extend the database by including Turkish value added and employment figures. However excluding Turkey, one of the largest middle income economies[9] and a highly cited typical MIT economy[10], from the construction of the representative MIT country may lead to biased results, and including Turkey in the MIT group would improve our understanding from the shift share analysis.[11] Therefore, we obtain sectoral value added and employment series for Turkey for the 1968-2013 period from the Turkish Statistical Institute (TurkSTAT) and incorporate Turkey in the analysis as one of the members of MIT country group.[12] In sum, our analysis covers 14 economies (4 NMIT and 10 MIT countries).

By using decomposition equation (1), we find that average labor productivity growth rates differ among MIT and NMIT countries significantly. While the average

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8 According to our criteria a country is stuck in the MIT if it has 8%-36% of the U.S. per capita GDP in 1960 and 2010. Since it has unsatisfactory relative convergence of per capita income levels on those of the rich economies.

9 It is the 18th largest economy in the world in 2014 with about GDP of USD 800 billion.

10 See for instance: Abdon et al. (2012), Eichengreen et al. (2013), Robertson and Ye (2013), Woo (2012) and Yeldan et al. (2012).

11 Moreoever, we need Turkish data to observe how productivity and its determinants behave over time since we will construct a growth model based on these insights eventually.

12 For details on our calculations: please see Yılmaz (2015b).

labor productivity growth rate is about 4.37% in the typical NMIT country, it is found to be 1.93% in the representative MIT country (Table 1).

Table 1

LP Growth Decomposition: NMIT vs. MIT Counries (%)

	LP Growth Rate	Within-sector Productivity Gains	SC Productivity Gains		
Representative Country			*Total*	*Static*	*Dynamic*
NMIT	4.37	3.70	0.67	0.85	-0.18
MIT	1.93	1.45	0.48	0.72	-0.24

Source: The GGDC Database, TurkSTAT and our own calculations.

To have a better idea about the differences in productivity growth rates across MIT and NMIT countries, we employ the decomposition equation (1). Based on equation (1), we find that while the average contribution of "within-sector productivity" gain is 3.70 points, and the contribution of aggregate structural change remains at 0.67 points in NMIT countries, these figures for the MIT countries are 1.45 and 0.48 points, respectively (Table 1).

To get an insight about labor productivity growth and its decomposition in Turkey, we reutilize the decomposition equation in (1). As depicted in Table 2, labor productivity growth in Turkey exceeds the labor productivity growth average for the MIT countries.

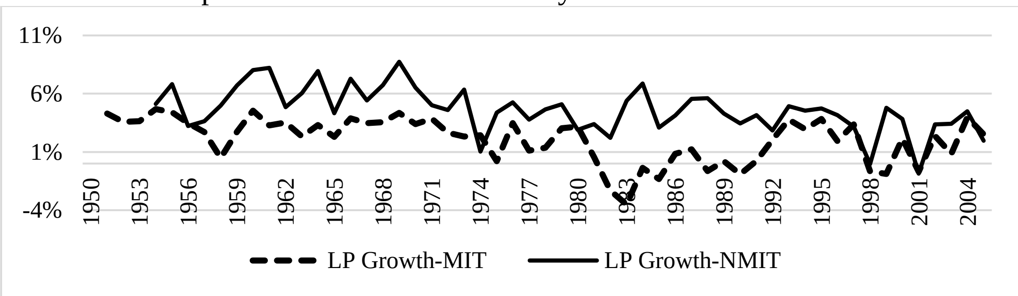
Table 2

Decomposition of Labor Productivity: Turkey vs. Representative Countries

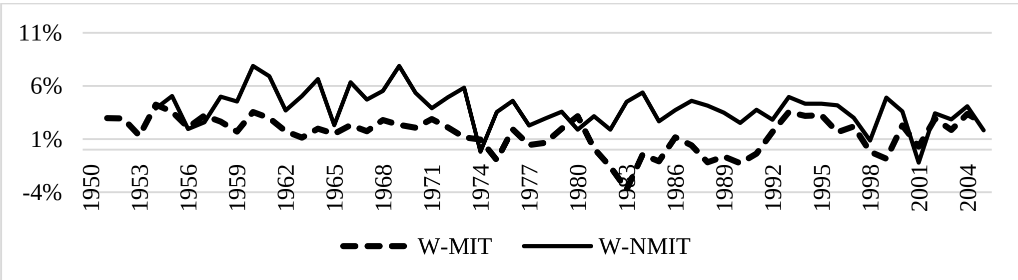
	LP Growth Rate	Within-sector Productivity Gains	SC Productivity Gains		
			Total	*Static*	*Dynamic*
Turkey	2.69	1.62	1.07	1.26	-0.19
MIT	1.93	1.45	0.48	0.72	-0.24
NMIT	4.37	3.70	0.67	0.85	-0.18

Source: The GGDC Database, TurkSTAT and our own calculations.

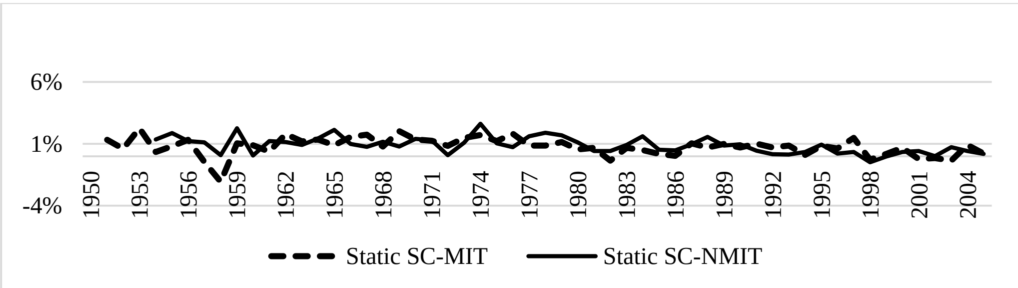
Figure 1
Decomposition of Labor Productivity: NMIT and MIT Countries



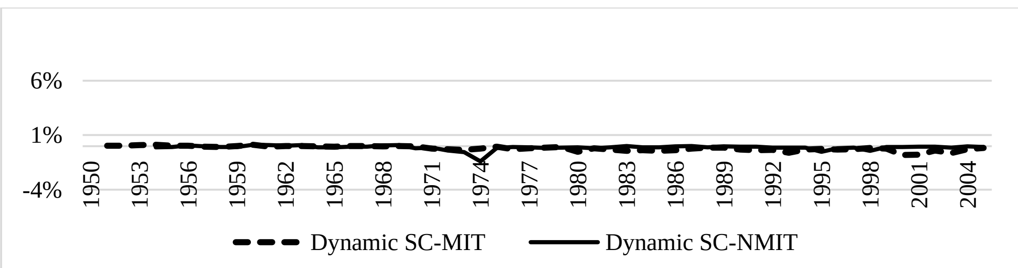
a.LP growth rate



b.Within sector



c.Static structural change productivity gains



d.Dynamic structural change productivity gains

Source: The GGDC Database, TurkSTAT and our own calculations.

Moreover, Turkey demonstrates a better performance in terms of total (static and dynamic) structural change productivity gains compared to both NMIT and MIT countries. The basic decomposition analysis reveals that Turkey's weakness primarily originates from within-sector productivity gains, and she should focus on improving factors leading to within-sector gains to boost her labor productivity growth.

As in Yılmaz (2015a), we think that Turkey's poor within-sector productivity performance could be related to her human capital level.[13] The relevant literature argues that having a world-class skilled and highly capable human capital, and highly innovative and competitive productive capacity are the main factors behind breaking out of the MIT (see for example Eichengreen et al., 2013; Felipe, 2012; Abdon et al., 2012; Hidalgo et al., 2007; Hausmann et al., 2005). In other words, it seems that Turkey's trap is especially due to her low human capital, and the ensuing repercussions on technology adaptation and innovation activities. Similar to our judgements, Altuğ et al. (2008) argue that Turkey should focus on structural measures to improve educational attainment and quality along with setting rule-based systems and institutions to enhance total factor productivity.

Identifying that poor performance in terms of within-sector productivity gains co-exists with low human capital leads us to contemplate how human capital should appear in the production function for a technologically backward country like Turkey. The related literature argues that human capital has an impact on productivity growth via various channels. For instance human capital promotes a country's technology absorption capacity, facilitates R&D and supports diffusion of technology especially in technologically backward economies. Nelson and Phelps (1966) argue that human capital in the follower country augments and facilitates rate of technology diffusion, Benhabib and Spiegel (1994) reiterate this result of Nelson and Phelps (1966) and demonstrate that technology diffusion and absorption capacity depend on education. The literature also discusses that human capital and education together determine domestic technology capability building (Banerjee and Roy, 2014), and support trade related knowledge spillovers[14] (Falvey et al., 2007; Teixeira and Fortuna, 2010) as well as international R&D spillovers (Coe and Helpman, 1995; Engelbrecht, 1997; Del Barrio-Castro et al., 2002; Seck 2012). The literature also mentions the existence of threshold human capital stocks to

[13] Yılmaz (2015a) compares Turkey to the rest of the trapped and non-trapped countries and identifies that Turkish human capital is critical to break out the trap. He claims that Turkish education system should be upgraded to yield both "skilled and high capability human capital" and "innovative and competitive productive capacity" to overcome the trap.

[14] According to Teixeira and Fortuna (2010), international trade emerges as a powerful direct contributor to long-term total factor productivity, especially in its embodied form, through the import of advanced machinery and equipment from developed economies.

benefit from FDI oriented technology spillovers (Borensztein et al., 1998; Xu, 2000). Moreover, human capital threshold could be an important factor that differentiates MIT and NMIT countries,[15] and could be the primary cause of a nonlinear relationship between technological backwardness and technological progress (Benhabib and Spiegel, 1994, 2005; Papageorgiou, 2002; Stokke, 2004).

Associating our findings with discussions in the relevant literature directs us to a theoretical framework that encompasses interactions between quantity and quality of educational attainment, human capital, domestic innovation efforts, transfer of foreign technology, technology absorption capacity and productivity. Based on our findings and the literature, in the next section we introduce our model.

3. The model environment

The model presented here follows the seminal R&D-based framework established by Romer (1990) where technological progress is considered to be the expansion in the methods of production and the increase in the number of varieties of products, which emerges as a result of intentional investment decisions of profit-maximizing firms. Our model differs from that developed by Romer in terms of the specification of the technological progress function: in a relatively backward economy, technological progress depends not only on innovative activities by domestic researchers but also on the economy's absorptive capacity of the existing world technology frontier. In that sense, following Benhabib and Spiegel (1994, 2005), the law of motion for technology in our model accounts for the ability of a country to realize its own technological innovations, as well as the capacity to adapt and carry out technologies developed abroad, which allows for the "catch-up" of technology, as in Nelson and Phelps (1966).

In the theoretical model, there are three sectors: a research sector, an intermediate goods sector, and a final goods sector. Using available human capital and existing technology, the research sector exploits both domestic R&D opportunities and imitation capabilities to develop new designs and blueprints for differentiated products. The intermediate goods sector uses these designs and blueprints to produce a large variety of intermediate goods for the use of the final good sector. In effect, one can consider that the intermediate goods sector encompasses the research sector, as long as the development of new designs and blueprints take place in the R&D department within the same firm. This sector comprises of monopolistically competitive firms since the manufacture of intermediate goods entails the fixed cost of investment in a design or blueprint, and these firms will have no incentive to produce under the conditions of perfect

[15] In the literature, there are many studies that argue South Korean success as a NMIT country depends on reform in education policies (Eichengreen et al., 2013; Jimenez et al., 2012; Jankowska et al., 2012).

competition. Finally, the final good sector is perfectly competitive and produces a single homogenous non-durable, consumption good using a variety of intermediate goods and labor in the production process.

The model is closed by assuming that there is a representative household which maximizes the present value of discounted intertemporal utility, and is endowed with a fixed endowment of labor. The fixed endowment of labor (or, total time) is allocated between pure production activities, and technology development, in other words, research activities. We assume that the time spent in education is useful solely for work in research sector (and thus labor with education works only in the research sector); furthermore, not only the quantity (i.e., years of schooling, or the time spent in education), but also the quality of education plays a determining role in this sector. The representative household is the owner of the firms in the economy, and earns dividend from intermediate goods sector firms. The perfectly-competitive final goods sector firms earn zero profits, therefore can be ignored in the specification of the household's endowments.

In the following sub-sections, we proceed first by the introduction of the characteristics of the sectors of the economy, the household behavior, and finally the nature of the equilibrium, both in transitionary periods and the balanced growth path.

3.1. Production and research activities

In the final goods sector, perfectly competitive firms produce a single, homogenous non-durable good with respect to Cobb-Douglas technology given as

$$Y = L_Y^{1-\alpha} \int_0^A x_i^{\alpha} di \, , \; 0 < \alpha < 1 \tag{2}$$

where Y is output, L_Y is the fraction of labor employed in final goods sector, x_i is the amount of intermediate good i, with $i \in [0, A]$, α is the share of payments to intermediate goods in total cost of production, A is the domestic technology index denoting the number of intermediate goods used in production of Y.

Given the productive technology in the final goods sector, competitive profits in the final goods sector are

$$\pi_Y = L_Y^{1-\alpha} \int_0^A x_i^{\alpha} di - \omega_Y L_Y - \int_0^A p_i x_i di$$

where ω_Y is the wage of labor engaged in final good production, and p_i is the price of intermediate good *i*. Profit maximization conditions in the final goods sector imply that

$$\omega_Y = (1-\alpha)\frac{Y}{L_Y}$$

$$p_i = L_Y^{1-\alpha}\alpha x_i^{\alpha-1} \text{ for all } i$$

Then in equilibrium, the demand for intermediate good *i* by the final sector firm can be found as

$$x_i = \left(\frac{p_i}{\alpha}\right)^{\frac{1}{\alpha-1}} L_Y \tag{3}$$

The flow of profits in intermediate good sector for firm *i* equals the price of the intermediate good *i* times the amount sold x_i minus the production costs. As in Papageorgiou (2002) and Barro and Sala-i-Martin (2004), we assume that once invented, the intermediate good *i* costs one unit of *Y* to produce. We further assume that the average and marginal cost of producing the intermediate good *i* is constant and normalized to 1. The producer of the intermediate good *i* is a monopolistic competitor, and thus is able to choose the price of the product, and solves the following profit maximization problem at each period

$$\max_{p_i}(p_i - 1)x_i \tag{4}$$

where x_i is given by equation (3). Replacing for x_i and maximizing the profits with respect to price p_i yields the unique monopoly price

$$p_i = \frac{1}{\alpha} > 1$$

i.e. the monopoly price p_i is constant and same for all intermediate goods *i*. The monopoly price thus represents the mark-up over the marginal cost of production, 1. Substituting this price in the equation (3), we obtain the aggregate quantity demanded and produced of each intermediate good *i*, which is also constant through time (it is assumed that labor does not grow) and the same for all firms *i* :

$$x_i = \left(\frac{1/\alpha}{\alpha}\right)^{\frac{1}{\alpha-1}} L_Y = \alpha^{\frac{2}{1-\alpha}} L_Y \text{ for all } i \tag{5}$$

Substituting p_i and x_i for all i in (4), we again obtain a unique, constant and positive flow of maximum profits for all intermediate goods producers (we now drop the subscript i as all firms are identical):

$$\pi = px - x = x(p-1) = \alpha^{\frac{1+\alpha}{1-\alpha}}(1-\alpha)L_Y \tag{6}$$

Finally, assuming that all firms are identical, with identical demand and identical price for an intermediate good, aggregate output Y can be obtained as

$$Y = L_Y^{1-\alpha}\int_0^A x_i^\alpha di = L_Y^{1-\alpha}Ax^\alpha = L_Y A\alpha^{\frac{2\alpha}{1-\alpha}} \tag{7}$$

As mentioned above, the research sector provides the intermediate goods sector with the new designs and the blueprints to produce new intermediate goods, and the number of the variety of these intermediate goods is A, which is the technology index for the domestic economy. The law of motion for the domestic technology index A, or the rule of growth of A specifies how the variety or the set of intermediate goods expands:

$$g_A = \frac{\dot{A}}{A} = H_{R\&D} + H_{ABS}\left(\frac{I_{MACH}}{GDP}\right)^\gamma \left[\frac{A}{A^*} - z\left(\frac{A}{A^*}\right)^2\right] \tag{8}$$

where $H_{R\&D}$ is the human capital used in R&D activities, H_{ABS} is the human capital used in absorption of world frontier technology, or imitation activities, $\frac{I_{MACH}}{GDP}$ is the share of machinery and equipment imports in GDP, and A^* is the world frontier technology. In this economy, available human capital H is allocated between pure R&D activities ($H_{R\&D}$) and technology transfer and imitation (H_{ABS}), i.e. $H=H_{R\&D}+H_{ABS}$. Lastly, the parameter γ denotes the elasticity of imitation-led domestic technological progress with respect to the share of import of machinery and equipment in GDP, and z is the curvature parameter of the quadratic absorption function.

Equation (8) represents a specification similar to that in Benhabib and Spiegel (1994, 2005) where technological progress depends both on domestic innovation efforts and on technological diffusion from abroad, or imitation. In equation (8), the first component of technological progress denotes the contribution of domestic innovation efforts by R&D. Here, domestic innovation activities depend on the human capital used in R&D, $H_{R\&D}$, and the effectiveness by which existing domestic technology level A is used. The second term in (8) captures the contribution of imitation efforts and transfer of existing world frontier technology, A^*. This term represents the extent to which existing world frontier technology is absorbed (in this case, as argued by Teixeira and Fortuna (2010), through import of machinery and equipment) by utilizing the available human capital for technology transfer and imitation, H_{ABS}, depending on how far the domestic technology A is from the world frontier technology A^*, or A/A^*. In fact, the technology-gap term A/A^* captures the benefits of "relative backwardness" in the imitation process, and as in Papageorgiou (2002) and Stokke (2004), there is a quadratic (hump-shaped) relationship between the technology gap and technological progress, or the productivity growth rate: the higher the technology gap is, the greater will be the opportunity to benefit from imitation and foreign technology, therefore the ability to imitate advances during the catch-up process as imitation costs decline, and the productivity growth rate increases. As the technology gap closes over time, adoption and imitation opportunities decline, leading to decreasing returns to learning and falling productivity growth rate. If the domestic technology level becomes exactly the same as the foreign technology level A^*, domestic technological progress will depend only on domestic innovation efforts through R&D.[16]

In the model, the fixed total labor endowment L, or time, is allocated between pure production activities for final good production, L_Y, and technology development, L_A :

$$L_A + L_Y = L$$

Recall that labor allocated in technology development is also labor with education. Labor in technology development, or labor with education L_A helps in building human capital, H. However, there is not a one-to-one relationship between labor with education and human capital: the quality of education is also a determinant of the level of human capital, and it determines the extent to which labor with education is transformed into productive human capital in technology development:

$$H = \varphi L_A \tag{9}$$

That is, each additional unit of L_A contributes to human capital at rate φ, $\varphi > 0$. Human capital is further disaggregated into $H_{R\&D}$ and H_{ABS} as

$$H_{R\&D} = s_{R\&D} H$$
$$H_{ABS} = (1 - s_{R\&D}) H$$

[16] In this case, domestic innovation effort contributes to the advance of the world technology frontier, but we do not explore this option since it is beyond the scope of this model.

where $s_{R\&D}$ is the share of human capital utilized in pure R&D (innovation) activities, $(1\text{-}s_{R\&D})$ is the share of human capital in technology transfer and absorption (imitation) activities.

3.2. Household behavior

The representative household in the model has the standard intertemporal utility maximization problem given as[17]

$$\max \int_0^\infty \frac{c(t)^{1-\theta}-1}{1-\theta} e^{-\rho t} dt$$

$$\text{subject to } \frac{d(Assets)}{dt} = r(Assets) + \omega_Y L_Y + \omega_A L_A - c$$

where $c>0$ is private per capita consumption, $1/\theta > 0$ is the elasticity of intertemporal substitution, and $\rho > 0$ is the time preference rate, ω_Y is the wage paid to labor in pure production activities, and ω_A is the wage paid to labor in technology development. In the household's budget constraint, household's assets equals the market value of firms, $V(t)$, and the interest rate r represents the return on firms' market value. By solving the optimal control problem, the household chooses the time paths of equilibrium consumption and asset holdings, and the equilibrium growth path of consumption per capita is given by the familiar Euler equation:

$$\frac{\dot{c}}{c} = \frac{1}{\theta}(r(t) - \rho) \tag{10}$$

3.3. Market value of firms

To find the interest rate that appears in the equilibrium growth path (10), we first define the present value of the returns from the production of intermediate goods, or the value of the intermediate good firm.[18] As Romer (1990:87) suggests,

> "The decision to produce a new specialized input (intermediate good) depends on a comparison of the discounted stream of net revenue and the cost P_A of the initial investment in a design. Because the market for a design is

17 There is no population growth in the model, and we assume L=1.

18 Since the final goods sector is perfectly competitive, the final goods sector firms do not earn any profits, and thus do not distribute any dividends; therefore we disregard the value of final good firms.

competitive, the price of the designs will be bid up until it is equal to the present value of the net revenue that a monopolist can extract".

Based on Romer's depiction, as in Papageorgiou (2002), we characterize the present value of a typical firm producing intermediate good[19] as

$$V(t)=\pi\int_t^{\infty} e^{-r(\eta-t)}d\eta=\alpha^{\frac{1+\alpha}{1-\alpha}}(1-\alpha)L_Y\int_t^{\infty} e^{-r(\eta-t)}d\eta \tag{11}$$

Let the price of design for a firm be ϕ, then according to Romer (1990), in equilibrium it must be that,

$$\phi=\alpha^{\frac{1+\alpha}{1-\alpha}}(1-\alpha)L_Y\int_t^{\infty} e^{-r(\eta-t)}d\eta \tag{12}$$

Differentiating both sides of equation (12) with respect to time (using the Leibniz Rule) yields

$$r=\frac{\alpha^{\frac{1+\alpha}{1-\alpha}}(1-\alpha)L_Y}{\phi}+\frac{\dot{\phi}}{\phi} \tag{13}$$

Next our task is to find ϕ. The wage of the labor engaged in technology development, ω_A, is equal to the marginal product of labor in the creation of new technology (or, new designs), multiplied by the price of each design, ϕ:

$$\omega_A=\frac{\partial\dot{A}}{\partial L_A}\phi \tag{14}$$

where

$$\dot{A}=H_{R\&D}A+H_{ABS}A\left(\frac{I_{MACH}}{GDP}\right)^{\gamma}\left[\frac{A}{A^*}-z\left(\frac{A}{A^*}\right)^2\right]$$
$$=s_{R\&D}\varphi L_A A+(1-s_{R\&D})\varphi L_A A\left(\frac{I_{MACH}}{GDP}\right)^{\gamma}\left[\frac{A}{A^*}-z\left(\frac{A}{A^*}\right)^2\right]$$

Therefore, the marginal contribution of L_A to creation of new technology (or, new designs) is

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19 Recall that we dropped subcript *i* as all firms are identical.

$$\frac{\partial \dot{A}}{\partial L_A} = s_{R\&D}\varphi A + (1 - s_{R\&D})\varphi A\left(\frac{I_{MACH}}{GDP}\right)^{\gamma}\left[\frac{A}{A^*} - z\left(\frac{A}{A^*}\right)^2\right] = \frac{\dot{A}}{L_A} \tag{15}$$

Then using (13), the wage of educated labor in research activities (12) becomes[20]

$$\omega_A = \frac{\dot{A}}{L_A}\phi$$

Since there is free entry into both the research sector and the final goods sector, the wages from these sectors must be the same in equilibrium, i.e. $\omega_Y = \omega_A$:

$$(1-\alpha)A\alpha^{\frac{2\alpha}{1-\alpha}} = \frac{\dot{A}}{L_A}\phi$$

$$\Rightarrow \phi = \frac{(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}L_A}{g_A} \quad \text{for all } i \tag{16}$$

with $g_A = \dot{A}/A$. Replacing (16) in (13) we obtain the interest rate or the return on firm's value,

$$r = \frac{\alpha^{\frac{1+\alpha}{1-\alpha}}(1-\alpha)L_Y}{\dfrac{(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}L_A}{g_A}} + \frac{\dot{\phi}}{\phi} = \alpha\frac{L_Y}{L_A}g_A + \frac{\dot{\phi}}{\phi} \tag{17}$$

And finally combining (17) with the household's equilibrium solution (10), we get

$$\frac{\dot{c}(t)}{c(t)} = \frac{1}{\theta}(r(t) - \rho) = \frac{1}{\theta}(\alpha\frac{L_Y}{L_A}g_A(t) + \frac{\dot{\phi}(t)}{\phi(t)} - \rho) \tag{18}$$

3.4. Equilibrium in the balanced growth path and in transition

In this single sector economy, we specify the economy-wide resource constraint as

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[20] This is equivalent to the concept of marginal revenue product of labor.

$$Y = C + Ax$$

here, Y is aggregate output, C is aggregate consumption, and Ax is the production of new intermediate goods (for example Papageorgiou, 2002; Barro and Sala-i-Martin, 2004). This resource constraint assumes that the intermediate good is a non-durable good and does not accumulate over time.[21]

Recall that in equilibrium we found that $Y = AL_Y \alpha^{\frac{2\alpha}{1-\alpha}}$ and $x = L_Y \alpha^{\frac{2}{1-\alpha}}$. Therefore, it is straightforward to show that aggregate consumption C is a constant function of technology level, A:

$$C = (1-\alpha^2)Y = (1-\alpha^2)AL_Y \alpha^{\frac{2\alpha}{1-\alpha}} \tag{19}$$

In per capita terms, consumption per capita growth is

$$\frac{\dot{c}}{c} = \frac{\dot{C}}{C} - n$$

Assuming that there is no population growth, *n=0*, from (19) the growth of per capita consumption is equal to the technological progress rate at any given time *t*:

$$\frac{\dot{c}(t)}{c(t)} = \frac{\dot{A}(t)}{A(t)} = g_A(t) \tag{20}$$

At the steady state, or the balanced growth path of this economy, all endogenous variables grow at constant rates, and as shown above, $\frac{\dot{c}}{c} = \frac{\dot{A}}{A} = g_A$ must be constant at the steady state. The steady state also requires that the price of a design, $\phi = \frac{(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}} L_A}{g_A}$ is constant. Therefore, $\frac{\dot{\phi}}{\phi} = 0$. Then at the steady state it must be the case that,

$$\frac{\dot{c}}{c} = \frac{1}{\theta}(r^{ss} - \rho) = \frac{1}{\theta}(\alpha \frac{L_Y}{L_A} g_A^{ss} - \rho) = g_A^{ss}$$

from which we can solve for the steady state value of g_A as

21 This assumption is made for simplicity of exposition which reduces the state variable to one (as A is the only state variable in the model).

$$g_A^{ss} = \frac{\rho}{\alpha L_Y / L_A - \theta} \tag{21}$$

The constant steady state rate of change in technology depends on the consumption behavior parameters ρ and θ, the factor share parameter α, and L_Y / L_A. In fact, the steady state technological progress rate is an increasing function of L_A, the share of labor allocated in the research sector, or in the creation of new technology.

In the transitional growth path of the economy, we established in equation (18) that[22]

$$\frac{\dot{c}(t)}{c(t)} = \frac{1}{\theta}\left[\alpha \frac{L_Y}{L_A} g_A(t) - \left[H_{ABS}\left(\frac{I_{MACH}}{GDP}\right)^{\gamma}\left(1-\frac{g_{WF}}{g_A(t)}\right)\left[\frac{A(t)}{A^*(t)} - 2z\left(\frac{A(t)}{A^*(t)}\right)^2\right]\right] - \rho\right]$$

Since $\frac{\dot{c}(t)}{c(t)} = g_A(t)$ everywhere in the equilibrium path (as given in equation 20),

$$g_A(t) = \frac{1}{\theta}\left[\alpha \frac{L_Y}{L_A} g_A(t) - \left[H_{ABS}\left(\frac{I_{MACH}}{GDP}\right)^{\gamma}\left(1-\frac{g_{WF}}{g_A(t)}\right)\left[\frac{A(t)}{A^*(t)} - 2z\left(\frac{A(t)}{A^*(t)}\right)^2\right]\right] - \rho\right] \tag{22}$$

from which we solve for the two roots of equilibrium g_A, as the solution is obtained from a quadratic equation. Among the two roots, we choose the positive and real root that converges towards the steady state. Lastly, given initial technology gap $A(0)/A^*(0)$, labor allocation L_Y / L_A, human capital allocated in technology absorption and imitation, H_{ABS} (which essentially depends on the quality of education φ), the share of imports of machinery and equipment in GDP, I_{MACH} / GDP, the world technology frontier progress rate g_{WF} , and the parameters $\alpha, \theta, \rho, \gamma$, and z, we are able to generate the equilibrium paths of $A(t)$ and $g_A(t)$, from the initial period towards the steady state.

4. Quantitative analysis of the model

In this section of the study, we quantitatively evaluate the equilibrium path of technological progress from the theoretical model described in the previous section utilizing some assumed and some computed parameters relating to the final goods and intermediate goods production and the research sectors, as well as household

[22] For a full derivation, please see Appendix.

behavior. We first evaluate the model under base parameter values, and then conduct simulations under alternative scenarios to see how the equilibrium path of technological progress is affected.

We make use of various sources to obtain the parameter values that help us to quantitatively evaluate the model's equilibrium. Concerning the production module of our model, we take the share of differentiated intermediate goods in total final good value added, α, as in Yeldan (2012), who calibrates this value as 0.647 using data from Turkey for the year 2005. Considering that in Turkey the average retirement age is 56 (for the 1990-2010 period) and the entry age to primary education is 7, the total number of years available for production activites and education is 49. The average years of schooling in Turkey (from the Barro-Lee database) is 5.5 years[23], and thus we calculate the fraction of total time spent in education, or educational attainment, L_A, as 11.2%, and the remaining fraction of total time spent in production activities as 88.8%.[24] The quality of education index φ for Turkey is calculated from Hanusek and Woessmann (2012) using the PISA exam score rankings of countries, and assuming that Taiwan (the highest ranking country) has the index of 1. The parameter $s_{R\&D}$ is proxied by the share of the number of R&D staff in population over the age of 25 with at least tertiary education in Turkey for the period after 1996 from the Unesco database. Since our task is to understand the factors which may help Turkey escape the MIT and join the NMIT countries group, we consider the world frontier technological progress rate g_{WF} as the average within-sector productivity growth rate of the NMIT countries, as given in Table 2. Here we have to point out that in our model the technological progress rate or the total factor productivity (TFP) growth is proxied by the within-sector labor productivity growth since the modeled economy is a single sector economy and the only source of growth of output is the change in labor productivity, or A (as given in the production function in equation 7). The share of machinery and equipment imports in GDP data comes from Turkish Statistical Institute for the average of the years 1998-2013, and the elasticity of within-sector productivity growth with respect to I_{MACH}/GDP, is calculated as 5.37% for the same period for Turkey. The initial technology gap, A/A*, is taken as 1/10 as in Papageorgiou (2002) and Stokke (2004). The curvature parameter in the technology absorption function, z, and the elasticity of intertemporal substitution in the utility function are both assumed to be 1.

As given in Table 2, Turkey's long-term within-sector productivity growth rate is found as 1.62%. Using equation (21), given this long-term growth rate and

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23 1990-2010 period. We thank the anonymous Reviewer for drawing attention to the fact that 5.5 is the average years of schooling of the general population, and not the labor force, which likely has a higher average years of schooling than the general population.

24 We thank the Anonymous Reviewer for drawing attention to this issue.

the L_A, α and θ values, we calibrate correspondingly that Turkey's time preference rate, ρ, is 0.066, which implies a discount rate[25] of 94%:

$$g_A^{ss} = \frac{\rho}{\alpha\left(\frac{1-L_A}{L_A}\right)-\theta} \Rightarrow$$

$$1.62\% = \frac{\rho}{0.647\left(\frac{1-0.112}{0.112}\right)-1} \Rightarrow \rho = 0.066$$

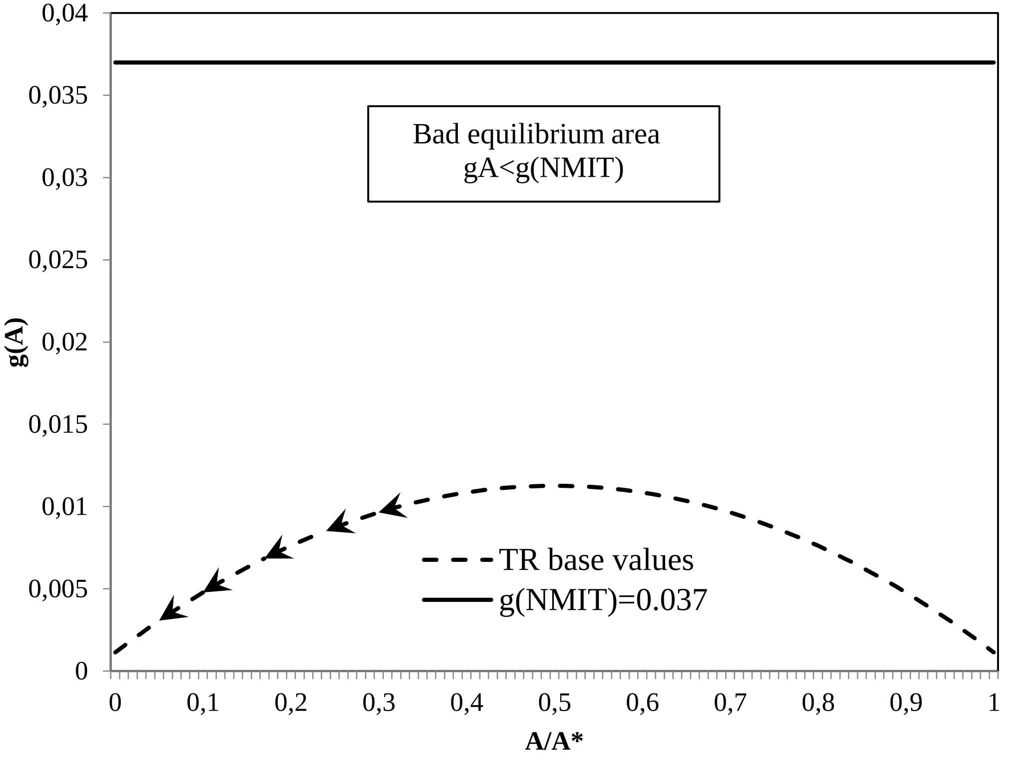
Table 3
Model's baseline parameter values

Parameter description	*Symbol*	*Base value*
Share of differentiated intermediate goods in total value added	α	0.647
Fraction of time spent in education	L_A	0.112
Quality of education (EQ)	φ	0.44
Share of researchers	$s_{R\&D}$	0.023
NMIT countries technological progress rate	g_{WF}	0.037
Share of machinery and equipment imports in GDP (m)	I_{MACH}/GDP	0.0405
I_{MACH}/GDP elasticity of technological progress	γ	0.0537
Initial technology gap	$A(0)/A^*(0)$	1/10
Curvature parameter in absorption function	z	1
Elasticity of intertemporal substition	$1/\theta$	1
Time preference rate	ρ	0.066

Initially, we evaluate the model under given baseline values for Turkey. Under the baseline values and with a long-term within-sector productivity growth rate of 1.62%, the Turkish economy is not able to catch-up with the NMIT economies, which have a long-term within-sector productivity growth rate of 3.7%, and end up in the bad-equilibrium area (Figure 2)

25 Discount rate is $\beta = \frac{1}{1+\rho}$

Figure 2
Quadratic Technological Change Function with Baseline Values



We then find that even though the Turkish economy started with the 3.7% growth rate of the NMIT countries, the average years of schooling in Turkey should be at least about 9.3 years to keep growing at this growth rate (L_A in Turkey should be at least about 19%):

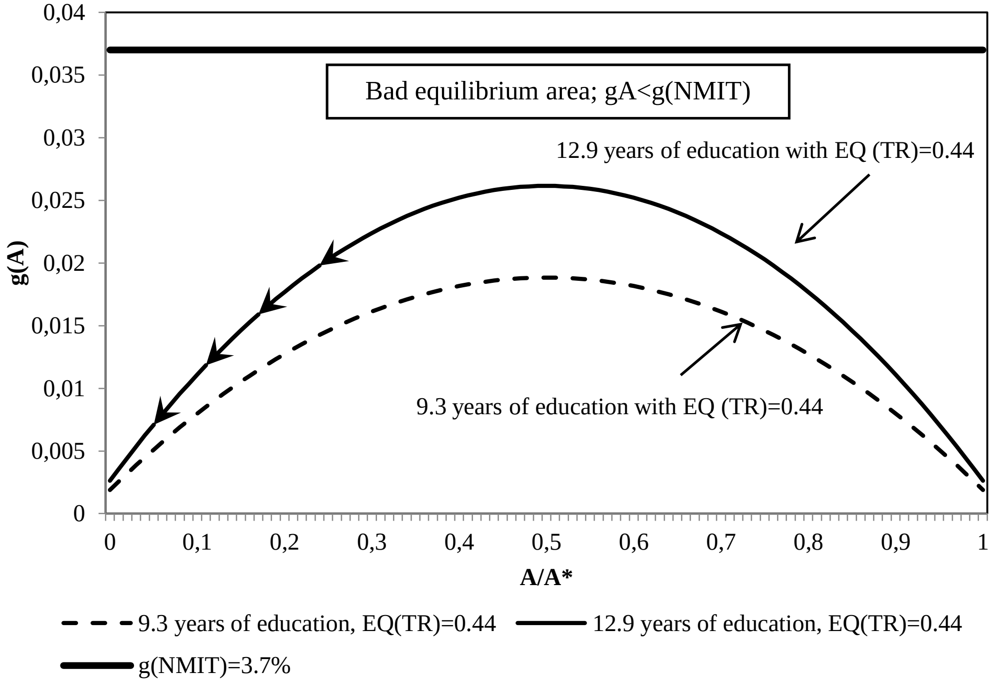
$$g_A^{ss} = \frac{0.066}{0.647\left(\frac{1-L_A^*}{L_A^*}\right)-1} = 3.7\% \Rightarrow L_A^* = 0.19$$

However, in order for the catch-up process to take effect, the Turkish technological progress rate must reach and remain above the world frontier technological progress rate (so that the technological gap closes); therefore we conclude that with the existing 5.5 years of schooling, and even with 9.3 years of schooling, the Turkish economy is far from catching up with the world frontier (Figure 3).

Next we examine whether about 12-13 years of schooling (similar to the US case) helps the Turkish technological progress rate attain convergence, or catch-up process with the NMIT countries. We see that an increase in the years of schooling is not sufficient to raise the inverted-U shape depicting the growth or technological progress dynamics of the Turkish economy above the g_{WF} border, as shown in Figure 3, and again the Turkish technological progress rate reaches a bad equilibrium with a decreasing A/A*, or an increasing technology gap away from the world frontier, which causes the Turkish economy to remain in the MIT.

Figure 3

Quadratic Technological Change Function with Alternative Schooling Rates



Therefore, in order to initiate the catch-up process which will lead the Turkish economy out of the MIT, either there must be an increase in the schooling rate well above the 12.9 years mark, or there must be improvements in other initial conditions, such as the quality of education which will improve human capital given the years of schooling, an increase in the share of imports of capital goods in GDP, which will elevate the country’s ability to benefit from foreign technology, and/or an increase in the share of researchers in educated population, which will help raise technological progress rate through innovation.

In Figures 4.a and 4.b, we show the effect of increasing Turkey's education quality from 0.44 first to that of US (φ=0.77), and then to that of South Korea (φ=0.95). We first determine that given the schooling rate of 12.9 years, the index of quality of education must be at least above 0.63 for the Turkish economy to set the catch-up process in motion. Therefore, to illustrate the catch-up process, we set the index of education quality at φ=0.65. In Figure 4.a, this case is shown by the lower solid inverted U-line crossing the horizontal g_{WF} line. Increasing the index of quality of education has two positive effects on the convergence or catch-up process leading to an exit from the MIT: (i) it decreases the necessary initial technology gap, A/A*, the threshold to start the catch-up process (so that a lower threshold of A/A* would be sufficient to set the catch-up process in motion); and (ii) it decreases the final technology gap, i.e. leads to a larger A/A* in the long run. In fact, a lower threshold would imply that the country has higher opportunities to benefit from foreign technology, leading first to an increase in the technological progress rate above the world frontier technology progress rate. Increasing the education quality enhances human capital for a given rate of schooling, and thus enhances R&D activities, and also augments imitation activities, i.e. raises the extent to which domestic technology benefits from import of capital goods. Thus, as shown in Figure 4.b, we can claim that raising the education quality has both a positive level effect on technological progress rate (through innovation), and also a positive growth effect (through imitation). Increasing the education quality first increases the technological progress rate in the initial period, and also speeds up the catch-up process. Then, over time as technology gap closes, and as imitation opportunities as well as benefits from foreign technology decrease, the g_A also decreases, but always remains above the g_{WF}. Eventually, the economy settles at some A/A* level where both A and A* grow at the same rate, $g_A = g_{WF}$. Here, the higher the initial benefits from foreign technology are, the higher will be the growth in domestic technology progress rate, and therefore the closer will be the domestic technology A to the world frontier technology, A*, i.e. A/A* will be higher at the long run (or steady state) equilibrium (Figure 4.a).

Figure 4.a

Quadratic Technological Change Function with Alternative Education Quality Indices

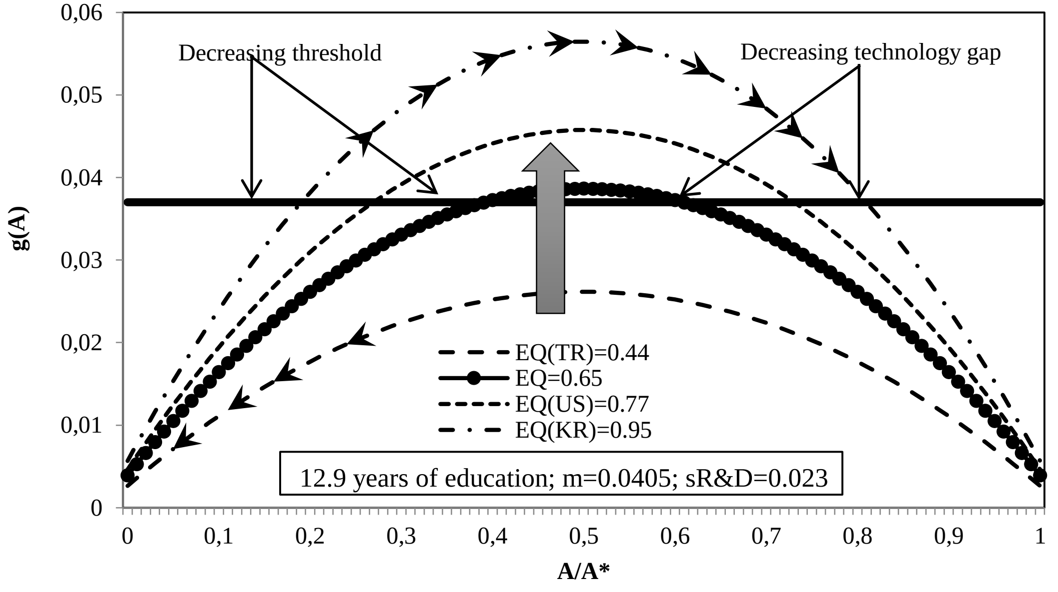
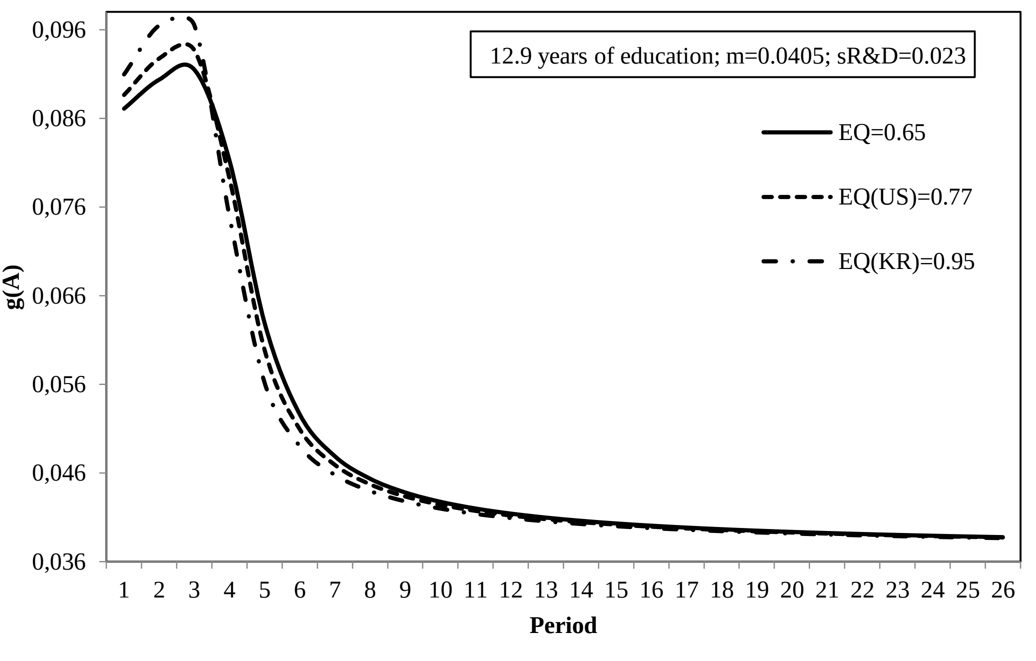


Figure 4.b

Transitional Path of g_A with Alternative Education Quality Indices



Using the model, we also examine the effect of raising the share of import of capital goods in GDP from 4.05% (the Turkish average) to 10%, then to 20%. In this simulation, we assume that years of schooling is 12.9, and the index of quality education is 0.65.[26] In Figure 5.a and b, we illustrate how the path of technological progress rate changes with changing I_{MACH}/GDP (m) parameter. We can regard the increase in m as an increase in technology transfer from abroad, and thus m parameter appears only in the absorption, or the imitation component of technological progress function. As in the increase in education quality, the increase in m has the effect of decreasing the technology gap threshold, and decreasing the final technology gap. Decreasing the technology gap threshold implies that the ability to imitate and benefit from foreign technology increases with increasing m. As the ability to imitate and the benefit from foreign technology increase, the g_A increases. But as imitation costs (i.e. design price) increase and as imitation opportunities decline over time, there will be less and less benefits that will turn into creation of new technology, and therefore g_A will start to decline. In the long run, g_A will converge towards g_{WF} and will remain there at the steady state, leading to a constant A/A*. In fact, the lower the initial threshold is, the higher will be the g_A above the g_{WF} during the catch-up process, and thus the higher will be the A/A* at the steady state equilibrium eventually.

[26] As mentioned above, we assume these parameter values in order to initiate the catch-up process.

Figure 5.a

Quadratic Technological Change Function with Alternative IMACH/GDP Values

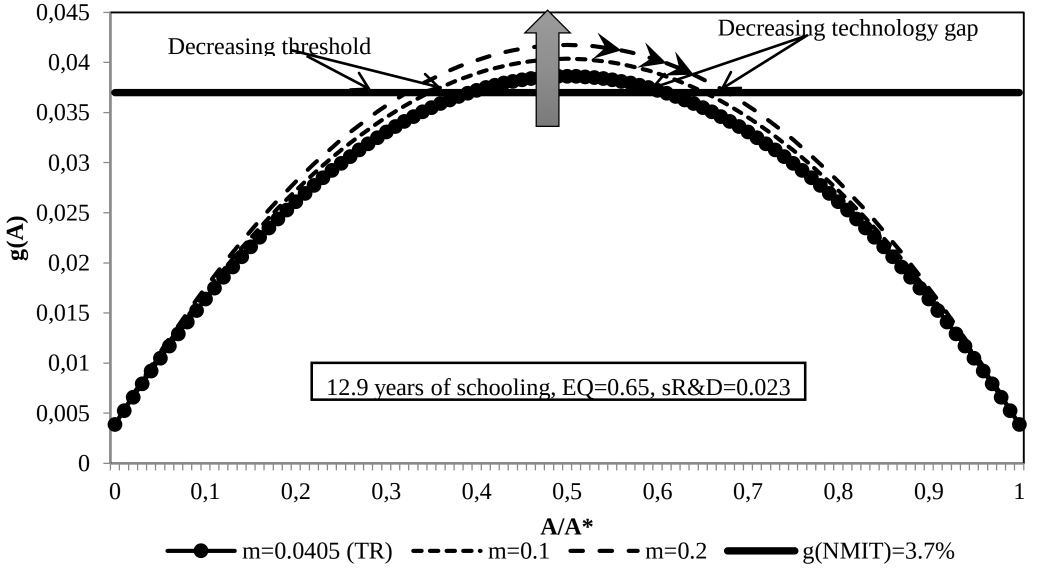
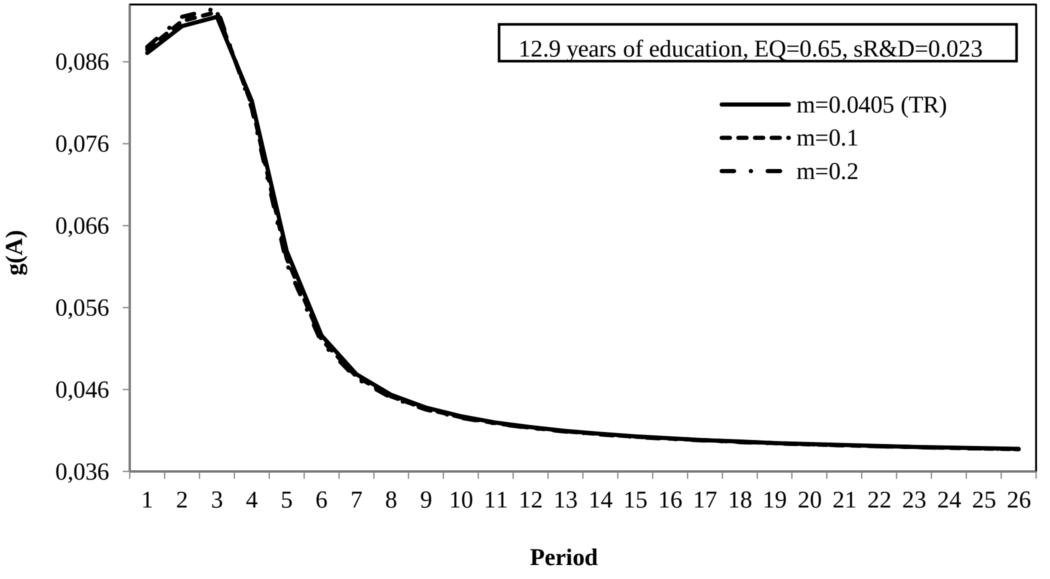


Figure 5.b

Transitional Path of gA with Alternative IMACH/GDP Values



In Figure 6.a, increasing the share of researchers $s_{R\&D}$ decreases the necessary initial technology gap, A/A*, the threshold to start the catch-up process, and lowers the final technology gap, i.e. higher A/A* in the long run. However, it has no definitive effect on technological progress growth rate (as depicted by the perfectly parallel shift of the inverted-U function in Figure 6.a, and thus no discernible effect in the transitional path in Figure 6.b) because of perfect substitutability between human capital in innovation and human capital in absorption. Changes in $s_{R\&D}$ only affects composition of human capital and the amount of available human capital remains constant (while more human capital is devoted to innovation, at the same time, less is available for absorption and imitation).

Figure 6.a
Quadratic Technological Change Function with Alternative sR&D Values

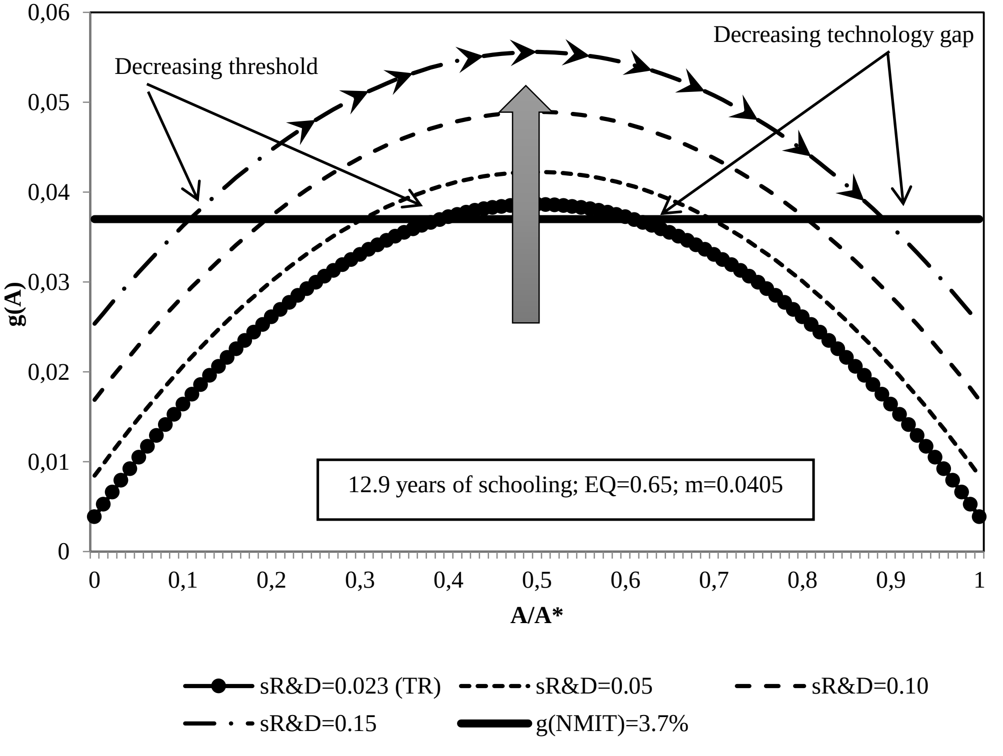
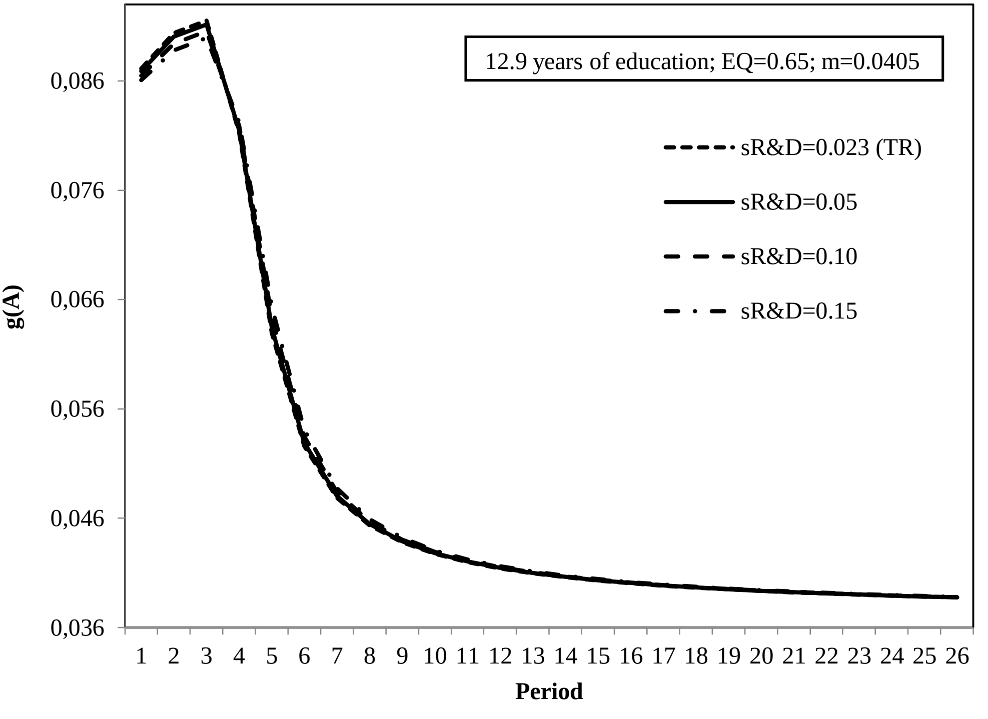


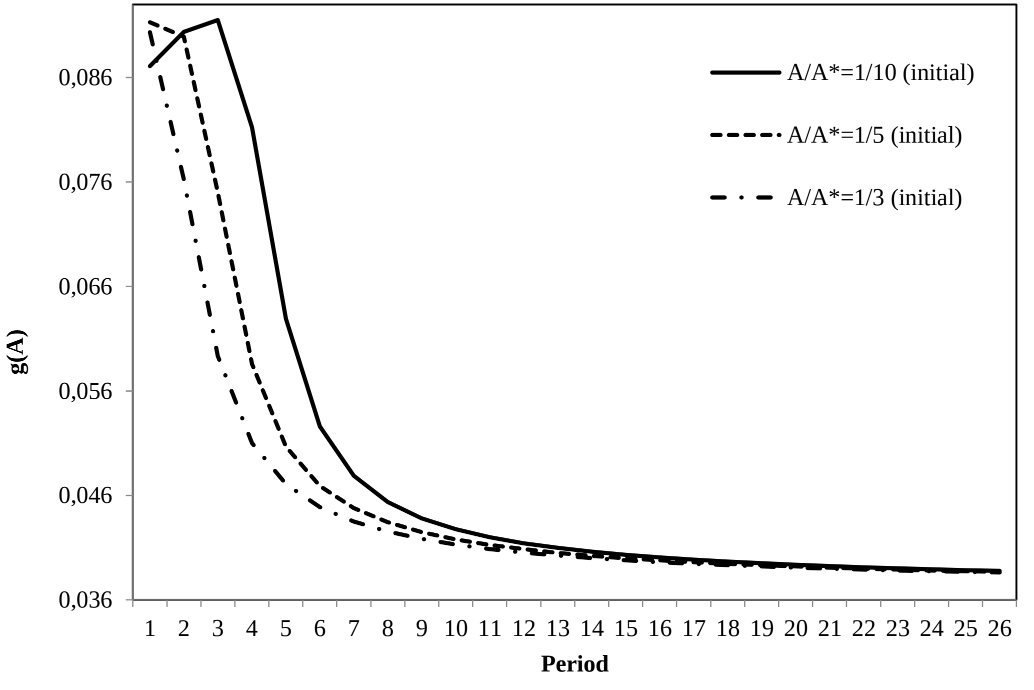
Figure 6.b
Transitional Path of gA with Alternative sR&D Values



Lastly, decreasing the initial technology gap, or increasing A(0)/A*(0) exogenously implies that holding all else constant, the economy is closer to the world frontier technology at the initial period. Decreasing the initial technology gap only has a transitory effect on the technological progress rate: in this case, the transitional path as given in Figure 7 shifts to the left, suggesting that the convergence towards the steady state equilibrium is faster and the catch-up process takes less time.

Figure 7

Transitional Path of g_A with Alternative Initial Technology Gap Values



In interpreting the quantitative results obtained from the model, one has to bear in mind that the policy changes introduced to stimulate growth (such as the change in years of schooling, change in education quality index concerning government's education policy, and the change in share of researchers concerning R&D expenditures policy) are exogenously given, holding all else constant. Such policy changes imply real costs as well as opportunity costs as the government (or the society) shifts resources away from alternative activities towards education and R&D. Although such costs are not dealt with here, one can suppose that the higher they are, the higher will be their distortionary effect on growth. However, existence of these costs would not affect the positive direction of the relationship between these policy elements and growth; it would only affect the strength of the relationship.

5. Concluding remarks

The MIT countries are a group of developing countries which have not been able to demonstrate sufficient progress towards successfully catching up with the relatively rich countries, for an extended period of time. Inability to raise labor productivity growth to adequate levels can be considered as one of the main culprits as to why they fail to realize convergence with relatively advanced countries.

Turkey, being among these middle income countries which lack convergence capabilities towards the group of rich countries, also lagged behind due to her poor within-sector productivity gains. Moreover, we argue that Turkish human capital is insufficient quantitatively and qualitatively, and her innovation and competitiveness performances are unsatisfactory to initiate catch-up with advanced economies.

Our theoretical framework highlights interactions between quantity, as well as quality of educational attainment and human capital, domestic R&D efforts, transfer of foreign technology, technology absorption capacity and productivity. The model points out that in order to achieve convergence with advanced economies, Turkey needs to raise the rate of technological change above the world frontier technological progress rate, by increasing technological absorptive and innovative capacity.

We show that by increasing the years of schooling, educational quality, the share of capital goods imports in GDP, not only the level of technology will improve, but also the rate of change in technology and labor productivity growth will improve, making it possible for Turkey to eventually experience catch-up with the advanced economies. Moreover, increasing the share of researchers in overall educated population helps to avoid the trap by decreasing thresholds to start the catch-up and increasing relative domestic technology levels.

Our findings put emphasis on the role of human capital development policies especially to catch up with the advanced economies. With regards to human capital, policy makers should design an education system that prioritizes skill and capability formation required for technology absorption and innovation-driven economic growth. It seems that this is the unique way to experience productivity and innovation driven growth. Both growth theory and empirical evidence make it clear that without having world-class human capital, it would not be possible for Turkey to escape the Middle Income Trap.

An important limitation of the model in this paper concerns the optimal choice of time devoted to work versus education (the L_A and L_Y values in the model). In the present model, this allocation is given exogenously, and further research will involve endogenizing this allocation so that the representative household's choice of work versus education, and thus enhancing human capital, presents a trade-off.

Our model presents further limitations to analyze some of the important real-world issues observed in developing countries like Turkey, such as surplus labor, and the reallocation of agricultural labor to services and industry, or to higher productivity activities as physical capital accumulates and as the economy grows.[27] In that sense, the model's full employment assumption in the labor market is noteworthy, as there is no mechanism in the model to allow for the absorption of any surplus labor, or reallocation of labor to higher productivity activities. Nevertheless, various papers in the relevant literature make use of similar modeling frameworks to the one employed in the present study to examine the growth in the long-run by abstracting from the stated real-world issues.[28]

Appendix

In the transitional growth path of the economy, the term representing the change in the price of design (or the value of the firm in equilibrium) is not necessarily constant over time, therefore *r(t)* and consequently $\dot{c}/c$ is not constant; at any given period *t*,

$$\frac{\dot{c}(t)}{c(t)} = \frac{1}{\theta}(r(t)-\rho) = \frac{1}{\theta}(\alpha \frac{L_Y}{L_A}\frac{\dot{A}(t)}{A(t)} + \frac{\dot{\phi}(t)}{\phi(t)} - \rho) \tag{A1}$$

We found in (16) the equilibrium price of each design as

$$\phi = \frac{(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}} L_A}{g_A} = \frac{(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}} L_A}{H_{R\&D} + H_{ABS}\left(\frac{I_{MACH}}{GDP}\right)^{\gamma}\left[\frac{A}{A^*} - z(\frac{A}{A^*})^2\right]}$$

Then, we derive the rate of change in the price of design that appears in equation (A1) as follows:

$$\frac{\dot{\phi}}{\phi} = -\left[H_{ABS}\left(\frac{I_{MACH}}{GDP}\right)^{\gamma}\left(1-\frac{g_{WF}}{g_A}\right)\left[\frac{A}{A^*} - 2z\left(\frac{A}{A^*}\right)^2\right]\right]$$

Where $g_{WF} = \dot{A}^*/A$ is the rate of change in world technology frontier. Consequently, in the transitional path of the equilibrium we have,

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27 We thank the anonymous referee for pointing this out.

28 For instance, Chen and Funke (2013) use a similar endogenous growth modeling framework to study China's economic growth and catch-up dynamics since 1980.

$$\frac{\dot{c}(t)}{c(t)} = \frac{1}{\theta}(r(t) - \rho)$$

$$= \frac{1}{\theta}(\alpha \frac{L_Y}{L_A} g_A(t) + \frac{\dot{\phi}(t)}{\phi(t)} - \rho)$$

$$= \frac{1}{\theta}\left[\alpha \frac{L_Y}{L_A} g_A(t) - \left[H_{ABS}\left(\frac{I_{MACH}}{GDP}\right)^{\gamma}\left(1 - \frac{g_{WF}}{g_A(t)}\right)\left[\frac{A(t)}{A^*(t)} - 2z\left(\frac{A(t)}{A^*(t)}\right)^2\right]\right] - \rho\right]$$

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Özet

Teknolojik değişim, beşeri sermaye ve emilim kapasitesi: Türkiye Orta Gelir Tuzağı'ndan çıkabilir mi?

Bu çalışmada, Türkiye gibi bir Orta Gelir Tuzağı ülkesinin tuzaktan kurtularak gelişmiş ülkelere yakınsayabilmesi için teknolojik gelişim hızının dünya sınır teknolojik gelişim hızından yüksek olması ve teknoloji emilim kapasitesini artırması gerekliliği görüşü dikkate alınarak içsel bir büyüme modeli kurgulanmıştır. Çalışmada okullaşma yılının, eğitim kalitesinin ve sermaye malı ithalatının GSYİH'ya oranının artışıyla hem teknoloji seviyesinin hem de teknolojinin gelişim hızının ve verimlilik kazanımlarının artacağı ve bu sayede Türkiye'nin tuzaktan kurtulmasının mümkün olabileceği gösterilmektedir. Ayrıca, eğitimli nüfus içinde araştırmacıların oranının artışı yakınsama sürecini başlatacak eşikleri azaltarak tuzaktan çıkabilmeye yardım edecek ve yerli teknolojinin dünya sınır teknoloji seviyesine oranını artıracaktır.

Anahtar kelimeler: İktisadi büyüme, verimlilik, yapısal değişim, orta gelir tuzağı.

JEL kodları: O11, O40, O47.