Economic Growth and Technological Progress in Turkey: An Analysis of Schumpeterian Mechanisms

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Abstract

This paper studies a second-generation Schumpeterian model to understand the nature of technological progress and economic growth in Turkey. It identifies some structural parameters numerically and tests whether certain Schumpeterian mechanisms work. Results show that, while horizontal (product) innovation works as determined in theory, vertical (process) innovation does not operate in the long run. Since the paper directly estimates the structural forms originating from the general equilibrium of the model economy, results do not carry any endogeneity bias. The paper also explains, in a quite transparent way, why the Turkish economy did not converge to frontier economies. The most appropriate policy under resource constraints is to strengthen the incumbent firms and support their growth, and the formation of new enterprises is not a policy priority.

Keywords: R & D, entry, process innovation, product innovation, productivity, policy.

JEL Classification Codes: O32, O41, O50.

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1. Introduction

Modern firms initiate and pursue costly research and development (R & D) projects. The main motivation behind these very investments is the expectation of higher productivity levels, larger market shares, and increased profits. One of the main streams of literature in the field of economic growth, *the endogenous growth theory*, dominantly builds upon this more or less Schumpeterian view of innovative activity to explain *how* and *why* economies experience intensive economic growth in the long run (Schumpeter, 1934).[1] Mechanisms studied by early contributors such as Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992) are all about innovations resulting from the purposeful activities of entrepreneurs and business firms.

The Turkish economy exhibits intensive economic growth in the long run. Real GDP per capita, in purchasing power parity corrected terms, grows at an average annual rate of around 2.5% (The Maddison Project, 2013; Feenstra et al., 2015). While this long-run rate is considerably lower than those recorded by growth miracles such as South Korea, the Turkish economy has successfully sustained this low-growth equilibrium from 1870s to the present day and avoided a permanent decline relative to the frontier economies.

The existing literature on the macroeconomic patterns and prospects of economic growth in Turkey, with or without microeconomic foundations, does not have a Schumpeterian focus (see, e.g., Altuğ et al., 2008; İsmihan and Metin-Özcan, 2009; Adamopoulos and Akyol, 2009; Çiçek and Elgin, 2011; İmrohoroğlu et al., 2014; Üngör, 2014). Besides, a few papers that build upon Schumpeterian notions do not provide empirical tests of the main mechanisms at work (Yeldan, 2012; Author; YEAR; Yılmaz and Saracoğlu, 2016). The primary purpose of this paper is to close these gaps in the literature.

The paper demonstrates that an analysis that takes the rich microeconomic structure of a particular class of Schumpeterian models is feasible. Here, this particular class refers to the dynamic (general) equilibrium models first appeared in the literature in around 1998. A short list of the most influential works along this line of research includes Aghion and Howitt (1998, Ch. 12), Dinopoulos and Thompson (1998), Peretto (1998a, 1998b), and Young (1998). In these second-generation Schumpeterian models, the technology landscape of the economy is represented by a subset in $\mathbb{R}^2_+$, i.e., a *plane*, with product innovations on the horizontal axis (entry) and process innovations on the vertical axis (in-house R & D). As very recently reiterated by Peretto (2016), these models are *robust* models of endogenous growth since the usual prediction of sustained exponential and fully endogenous growth holds for large subsets of the parameter space.

The paper builds upon *the Manhattan Metaphor* model of Peretto and Connolly (2007) and presents a theoretically-informed econometric analysis characterized by two distinct tasks: *The first task* is to test whether product innovation in Turkey works in accordance with the Schumpeterian model. In theory, the number of firms per capita has a logistic law of motion originating from the general equilibrium of the model economy. The nonlinear least squares estimates using the data from TurkStat (2012) confirm that, from 1965 to 2011, the horizontal dimension of the technology landscape expanded in a way consistent with the Schumpeterian mechanism. *The second task* is to test the operation of process innovation in Turkey. The general equilibrium of the model economy implies a well-defined law of motion for aggregate total

[1] The German original of this work by Schumpeter was published in 1911.

factor productivity (TFP) as well. Contrary to the case of the number of firms per capita, however, the nonlinear least squares fit for aggregate TFP that uses the Penn World Tables (PWT) data provided by Feenstra et al. (2015) is remarkably poor for the period from 1950 to 2011, and this allows us to infer certain ranges of values for some structural parameters. These inferences in turn strongly indicate that Schumpeterian vertical innovation process is not a statistically significant source of productivity growth in Turkey.

This paper contributes to the literature by rigorously showing that the technology landscape of the Turkish economy expands in its horizontal dimension only, and three aspects of the present analysis are worth emphasizing: First, since the paper estimates the structural forms directly and identifies structural parameters, results do not carry an endogeneity bias. Second, the knowledge of exactly which innovation channel works and which does not sheds light on why Turkey has been unsuccessful in converging to frontier economies; both theory and empirics indicate that horizontal innovation cannot sustain fast economic growth in the long run (Laincz and Peretto, 2006; Peretto and Connolly, 2007; Peretto, 2016). Finally, thanks to the identification of some structural parameters, results lead us to at least one concrete policy message: If resources are limited, the priority would be the growth of incumbent firms and their in-house R & D activity, not the entrance of new enterprises. This message obtained through an analysis of macro data in this paper is quite consistent with Özçelik and Taymaz's (2004) similar message originating from the analysis of firm-level data.

Section 2 presents a brief survey of the literature on economic growth and productivity in Turkey. Section 3 presents a story of the rise of second-generation Schumpeterian models in growth theory. Section 4 introduces how various second-generation Schumpeterian models construct the technology landscape of an economy with product and process innovations. Section 5 builds upon Peretto and Connolly's (2007) model specifically and derives the mathematical equations to be estimated. Section 6 describes data and presents the main estimation results. Section 7 provides a summary and a discussion, and Section 8 concludes with a remark.

2. Economic Growth and Productivity in Turkey: A Very Short Review

The Maddison Project's (2013) data indicate that real GDP per capita in 2010 is around 11.5 times larger than its 1923 level. This data, measuring real GDP per capita in purchasing power parity corrected dollars, implies an average growth rate of 2.53% per annum. Similar results follow from an analysis of the PWT data provided by Feenstra et al. (2015): Real GDP per capita in Turkey grows at an average annual rate of 2.24% from 1950 to 2011.

This growth performance is far from being impressive in comparison with those of Asian growth miracles and of fast growing emerging markets. But Turkey's experience is not a growth disaster either. The familiar boom-bust cycles form a regular evolution around a stable growth trend in the long run.

Recent years have witnessed the publication of several research papers presenting growth accounting exercises for Turkey and quantifying the sources of economic growth. These papers build upon different assumptions, and the data used in these papers cover different episodes. The main results of these papers regarding the dominant source of economic growth thus differ.

Saygılı et al. (2005) analyze 1972-2003 data and estimate that aggregate TFP grows with a secular trend after 1980s. Altuğ et al. (2008) present a complementary growth-accounting exercise for the period of 1880-2005 and conclude that physical capital accumulation is more important than TFP growth especially before 1980s. Studies using disaggregated data for manufacturing industries also support the result that the role of TFP growth markedly differs before and after 1980; see Altuğ and Filiztekin (2006) for a detailed review. Saygılı and Cihan (2008) estimate production functions for the period of 1988-2007 using aggregate time series data and conclude that both physical capital and TFP are important in explaining economic growth. For the period of 1960-2004, İsmihan and Metin-Özcan (2009) present a growth-accounting exercise indicating that both TFP and physical capital have explanatory power. Building a two-sector model to study the role of agricultural productivity, Atiyas and Bakış (2014) provide growth-accounting results showing that TFP growth is significant especially in 2000s and especially in agriculture. Üngör and Kalafatcılar (2014) also focus on 2000s and their analysis of 2004-2012 data show that (i) broadly-defined labor productivity is important in explaining economic growth before the Global Financial Crisis but (ii) the post-crisis episode is characterized by the dominant role of the ratio of employment to the working age population.

Three papers that complement these studies via models with microeconomic foundations are those of Adamopoulos and Akyol (2009), Çiçek and Elgin (2011), and İmrohoroğlu et al. (2014). These papers explain the relative underperformance of Turkey with factors such as high income taxes, low labor force participation rates, and low agricultural productivity growth rates. However, the mechanisms by which aggregate productivity growth occurs and remains relatively low are not specified as endogenous (Schumpeterian) mechanisms. A Schumpeterian model that explains why the growth rate of aggregate TFP in Turkey remains alarmingly low has not been subjected to structural econometric evaluation before. This is precisely what this paper is after.

3. The Rise of the Second-Generation Schumpeterian Models

From mid-1950s to mid-1980s, the development recipes designed for the least developed countries and analyses of economic growth in advanced economies have largely built upon the neoclassical paradigm of economic growth and development (Solow, 1956; Swan, 1956): "*Consume less to invest more, and have fewer children*!" has been the main message in a universe where technological progress that implies a growing productivity per unit of human labor occurs as *deus ex machina* (or does not occur at all if the economy is stagnating in the long run).

This paradigm has shifted with the publication of Romer's (1986) and Lucas' (1988) papers that develop models featuring Marshallian externalities, respectively, for physical and human capital. Due to (positive) externalities, the rate at which factor accumulation occurs depends on the microeconomic fundamentals such as preferences and technologies. Put differently, economic growth has now been endogenous, demonstrated for the first time in satisfactorily rich dynamic general equilibrium frameworks.

The next biggest shift has occurred with the appreciation of the Schumpeterian view by Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992): Entrepreneurs and business firms deliberately allocate resources into innovative activities in search of higher market shares and higher profits. How fast real GDP per capita would grow has still been endogenous and once again in a dynamic general equilibrium framework, but these Schumpeterian models have also drawn concrete routes to policy designs for the purpose of affecting the long-run growth rate of the economy. To take just one example, research subsidies increase the long-run growth rate as they stimulate investments into innovative activities in theory.[2]

Perhaps the only significant empirical problem with these first-generation Schumpeterian models is the infamous scale effect: These models predict that, if the total workforce directed to R & D activities is to increase in the long run, exactly as it has done for the United States (US) economy in the second half of the 20th century, then the growth rate should increase proportionally. This is a prediction that sharply contradicts with the more or less stable growth rate of the US economy around 2% per year in the same episode (Jones, 1995a).

Some theorists including Jones (1995b) and Kortum (1997) have looked for a solution by changing the specification of the so-called *knowledge production function*, simply imposing some sort of decreasing returns to scale into this production technology. The end result has been devolutionary; the long-run growth rate of the economy has now been semi-endogenous and proportional to the exogenously-taken long-run growth rate of the labor force. This has once again meant that the policies may not alter the long-run growth rate of the economy; *the empire striking back*!

But others such as Aghion and Howitt (1998, Ch. 12), Dinopoulos and Thompson (1998), Peretto (1998a, 1998b), and Young (1998) have insisted on the robustness of specification and argue that, in Laincz and Peretto's (2006: 263) words, the scale effect is "*an error of aggregation not specification*." What these authors mean is simply that, while the total workforce directed to R & D activities increases, this workforce thinly spreads over an increasing number of innovative firms/sectors in the economy. This increasing number of innovative firms/sectors then eliminates the scale effect that follows specifically from the narrow structure of the first-generation models with only one innovating firm/sector. More specifically, the growth rate of firm-level productivity clearly increases with the flow of R & D workforce employed by the firm, but the expansion of the number of innovating firms catches up with the growth of economy-wide R & D workforce to imply a nonexplosive long-run growth rate of firm-level productivity. With firm-level productivities converging to their balanced growth paths with fixed and fully endogenous growth rates, the growth rate of aggregate TFP is also fixed and fully endogenous; *the return of the Jedi*!

4. The Technology Landscape in the Second-Generation Schumpeterian Models

The common element of the second-generation Schumpeterian models is a two-dimensional technology landscape. On the horizontal dimension/axis lie products. These products are either consumption goods or investment goods depending on the interpretation/construction of the model economy. The vertical dimension/axis typically records the quality or the productivity of each variety. The horizontal or product innovation is the introduction of new products, i.e., an expansion of product variety, and the vertical or process innovation is the growth of quality or

[2] Aghion and Howitt's (2009) 18-chapter textbook allocates 6 of the chapters to the discussion of growth policy. The titles of these chapters are instructive; "Fostering Competition and Entry," "Investing in Education," "Reducing Volatility and Risk," "Liberalizing Trade," "Preserving the Environment," and, finally, "Promoting Democracy."

productivity levels associated with products.

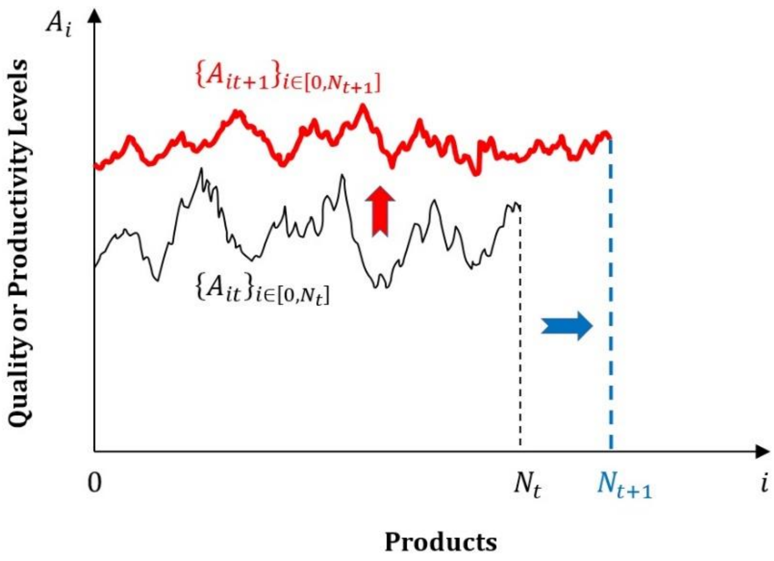

Figure 1: The Technology Landscape as a Subset in $\mathbb{R}_+^2$

Figure 1 pictures a typical two-dimensional technology landscape for an economy operating in discrete time t.[3] An index variable i is on the horizontal axis, satisfying $i \in [0, N_t]$ where N_t denotes the number of products in use at time t. $A_i > 0$ on the vertical axis indicates the level of quality or productivity associated with product i. The black line exemplifies an empirical distribution of A_i across i at time t. From t to $t+1$, horizontal innovation increases the number of products in use from N_t to N_{t+1}; the blue block arrow identifies the direction of horizontal innovation. In the meantime, vertical innovation increases the level of quality or productivity of each product; the red block arrow identifies the direction of vertical innovation. The red line then indicates the new empirical distribution of A_i across i at time $t+1$. Clearly, the technological sophistication of the economy increases with

$$\int_0^{N_t} A_{it} di. \tag{1}$$

The second-generation Schumpeterian models incorporate this two-dimensional view of technology into a dynamic general equilibrium framework in several ways. A brief discussion of these is now in order.

4.1 Products as Consumption Goods

Denoting by C_t a consumption aggregate and by X_{it} the flow of each product currently consumed, a Constant Elasticity of Substitution (CES) form may be imposed as in

[3] Nothing essential would be different or lost if a continuous-time framework is adopted to introduce the same notions.

$$C_t \equiv \left(\int_0^{N_t} (A_{it}X_{it})^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}} \tag{2}$$

where A_{it} is the quality level as introduced above and $\epsilon > 1$ is the preference parameter representing the elasticity of substitution across products. In such a case, consumers solve an intra-temporal problem of expenditure minimization given C_t and some properly defined aggregate price index P_t in addition to the usual inter-temporal problem of optimal saving/borrowing.

In an alternative specification with $C_t \equiv (\int_0^{N_t} X_{it}^{\frac{\epsilon-1}{\epsilon}} di)^{\frac{\epsilon}{\epsilon-1}}$, the vertical dimension of innovation is associated *not* with the quality of consumption good i but with the productivity of rival inputs in producing this good such that $X_{it} = F(A_{it}, K_{it}, L_{it}, \dots)$.

In both of these cases, the model specifies the so-called knowledge production functions for $\{A_{it}\}_i$ and N_t. These functions determine exactly how endogenous technological progress occurs.

4.2 Products as Investment Goods

It is quite often the case that products enter the model as investment goods, or, more specifically, as (reproducible) production inputs. Denoting by Y_t the flow of a final good produced at period t, we usually have a production function looking like

$$Y_t \equiv L_t^{1-\alpha} \left(\int_0^{N_t} (A_{it}X_{it})^{\alpha} di\right) \tag{3}$$

But exactly as in the case of consumption goods, there exists another alternative where the vertical innovation enters the model differently. With the final good production satisfying $Y_t \equiv L_t^{1-\alpha} \int_0^{N_t} X_{it}^{\alpha} di$, the production function for investment good i can be specified as in $X_{it} = F(A_{it}, K_{it}, L_{it}, \dots)$.

As in the case of consumption goods, the models with investment goods also specify how $\{A_{it}\}_i$ and N_t change as private agents direct resources into these innovative activities.

5. Tests of the Schumpeterian Mechanisms

This section describes two tests of Schumpeterian mechanisms in subsections 5.2 and 5.3. To proceed with clarity, however, a brief but more specific introduction of the underlying theory is essential and now in order.[4]

5.1 The Manhattan Metaphor

In Peretto and Connolly's (2007) continuous-time general equilibrium framework with infinitely-lived dynasties, real consumption per capita in the unique general equilibrium is

[4] The theoretical discussion here necessarily omits certain less central parts of the underlying theory for space considerations.

proportional to the economy's aggregate TFP level. The latter is determined endogenously by the co-evolution of the mass $N(t)$ of consumption goods in the horizontal dimension and the average $A(t)$ of productivity terms associated with the production of goods in the vertical dimension.[5] The logic is one of *arbitrage*; the real returns of all investments are equalized in equilibrium.

Omitting the time variable t for a neat look, Peretto and Connolly (2007: 343) describe consumer preferences via

$$C = N^{\omega-\frac{\epsilon}{\epsilon-1}}\left[\int_0^N C_i^{\frac{\epsilon-1}{\epsilon}}di\right]^{\frac{\epsilon}{\epsilon-1}} \tag{4}$$

where C denotes real consumption per capita as a Dixit-Stiglitz aggregate of real per capita consumption flows denoted by C_i for each good i, $\epsilon > 1$ denotes the elasticity of substitution, and N denotes the number of products each produced by a local monopoly. The *love-of-variety* effect, also known as the social return to variety, is represented by the parameter $\omega \geq 0$. The love-of-variety simply reflects how much consumer satisfaction increases when consumers have a larger menu of products to choose from.

Next, the production technology for each good in Peretto and Connolly (2007: 333) is specified as in

$$X_i = A_i^\theta\left(L_{X_i} - \phi\right) \tag{5}$$

where L_{X_i} is the flow of labor employed for the production of good i and $\phi > 0$ is the fixed operating cost.[6] In this production function, $\theta \in (0,1)$ is the "knowledge" elasticity of production at the firm level as the firm's accumulated stock A_i of "knowledge" increases its labor productivity.[7]

Given these fundamentals, the (symmetric) general equilibrium of the economy is characterized by the endogenous growth of real consumption per capita and aggregate TFP such that

$$C(t) \propto TFP(t) = N(t)^\omega A(t)^\theta. \tag{6}$$

Let $\Lambda e^{\lambda t}$ denote population where $\lambda > 0$ is the fixed population growth rate. Then, the equilibrium law of motion for the number of firms per capita $n(t) = N(t)/\Lambda e^{\lambda t}$ satisfies the logistic equation

[5] Peretto and Connolly (2007) denote average productivity by $Z(t)$ and its percentage growth rate by $z(t)$. In the remainder of this paper, $A(t)$ and $g_A(t)$ are used respectively for $Z(t)$ and $z(t)$. In addition, the (percentage) growth rate of $N(t)$ is denoted by $g_N(t)$. These are the only notational differences between this paper and that of Peretto and Connolly (2007).

[6] The fixed operating cost plays a central role in this type of endogenous growth models because it emphasizes one crucial difference between vertical and horizontal innovation, i.e., whether innovation puts a pressure on finite resources such as the labor force. The difference in turn clarifies why the two dimensions of innovation are complementary. See Peretto and Connolly (2007) for a discussion.

[7] The assumption of $\theta \in (0,1)$ is motivated by the fact that, for the economy to converge to a symmetric Nash equilibrium of R & D performing firms, θ must be sufficiently small given ϵ. See Peretto (1998b: 62, 76) for the associated analysis and proofs.

$$n(t) = \frac{n^*}{1+\Delta e^{-\upsilon t}} \tag{7}$$

where the meta-parameters Δ and υ are defined as in

$$\Delta = \frac{n^*}{n_0} - 1 \qquad \text{and} \qquad \upsilon = \beta \left[\frac{1-\theta(\epsilon-1)}{\epsilon-1}\right] - \rho. \tag{8}$$

Here, n_0 and n^* are respectively the initial and the steady-state (terminal) levels of $n(t)$, $\beta > 0$ is a technology parameter that decreases the cost of horizontal innovation, and $\rho > 0$ is the familiar subjective discount rate that discounts utility flows exponentially via $e^{-\rho t}$.[8]

Notice that the reduced-form logistic equation represents $n(t)$ only as a function of time. As it is typical for the logistic equation, $n(t)$ grows at a slow pace when t is small. The growth rate, however, gradually increases with t until it crosses the inflection point where the growth rate is maximum. Then, the growth rate starts decreasing with t, and $n(t)$ converges to n^* for $t \to +\infty$.[9] The Manhattan Metaphor enters the picture here: The Manhattan Island is the product market in this metaphor such that each newly established firm is a new tower built on Manhattan. Each such firm has to cover a "space" horizontally to have a strictly positive profit as the flow of profit increases with population through the market size effect and decreases with existing number of firms through competition. But, then, the number of monopolistically competitive firms that the economy can accommodate is limited with population growth. On the other hand, incumbent firms can vertically grow with new process innovations as it is always possible to build taller buildings that cover the same limited space horizontally. The genuine source of growth is then in-house R & D by existing firms as the number of firms located on the horizontal dimension only works as the physical capital of Solow's (1956) model.

For obvious reasons, the evolution of $TFP(t)$ represented by a reduced-form function of t is of interest as well. In logarithms, this function satisfies

$$\ln[TFP(t)] = \ln\left(A_0^{\theta} n_0^{\frac{1}{\epsilon-1}}\right) + g^* t + \frac{\gamma\Delta(1-e^{-\upsilon t})}{\upsilon} + \omega \ln\left(\frac{1+\Delta}{1+\Delta e^{-\upsilon t}}\right) \tag{9}$$

where g^* and γ are, again, meta-parameters that are non-negative (see below). The noteworthy thing about this solution is that $TFP(t)$ has one secular component governed by the term $g^* t$ and two transitory components governed by the term $e^{-\upsilon t}$.

The secular component is simply governed by how large the steady-state rate of economic growth is. Formally, we have

$$g^* = \omega g_N^* + \theta g_A^* \tag{10}$$

where (g_N^*, g_A^*) denotes the pair of (percentage) steady-state growth rates representing the growth of R & D outputs, respectively of goods as products and productivities as processes.

Clearly, the two transitory components that characterize the shape of the evolution of $TFP(t)$

[8] It is important to note that the logistic form for $n(t)$ is obtained under alternative specifications of the entry cost faced by innovators in the horizontal dimension and is therefore robust in a theoretical manner. See Peretto and Connolly (2007: 339-343).

[9] In other words, the growth rate of the logistic variable is a bell-shaped function of time.

both converge to zero for $t \to +\infty$. How exactly this convergence occurs, on the other hand, carries information about the structural parameters of the model through the meta-parameters γ, Δ, and υ. We have

$$\gamma = \theta(g_A^* + \rho) \tag{11}$$

where g_A^* itself is determined by parameters β, ϵ, θ, ϕ, and ρ and also, of course, by a parameter denoted by $\alpha > 0$ that governs how costly the vertical innovation is:

$$g_A^* = \frac{\theta(\epsilon-1)[\phi-(\rho/\alpha)]}{1-\theta(\epsilon-1)-(\rho/\beta)(\epsilon-1)} - \frac{\rho}{\alpha}. \tag{12}$$

5.2 The Horizontal Dimension of Innovation

To derive the equation that tests whether the horizontal dimension of innovation is active or not, we directly build upon (7) and write n_t in discrete time t as in

$$n_t = \frac{\pi_1}{1+e^{-\pi_2(t-\pi_3)}} + u_t \tag{13}$$

where (π_1, π_2, π_3) is a collection of parameters such that

$$\pi_1 = n^* \qquad \pi_2 = \upsilon \qquad \text{and} \qquad \pi_3 = \frac{\ln(\Delta)}{\upsilon}, \tag{14}$$

and u_t is a zero-mean error term which is distributed as a normal variable and is stationary.[10]

Clearly, the statistical significance of parameters in this logistic model would suggest that entrepreneurs in the horizontal dimension of the technology landscape are actively investing in the establishment of new business firms. Thus, a direct test of whether horizontal innovation is active or not in Turkey is how large the explanatory power of the logistic model is.

5.3 The Vertical Dimension of Innovation

The direct test of interest for the vertical dimension of innovation is feasible only if we impose a restriction for identification purposes. This restriction builds upon the assumption that the love-of-variety effect is nil, i.e., $\omega = 0$, so that economic growth in the long run is fully explained by process innovations. Thus, this restriction is more specifically about identifying the parameter θ and other determinants of g_A^*. With $\omega = 0$, (9) simply reduces into a nonlinear time-series regression in the form of

$$\ln[TFP_t] = \pi_1 + \pi_2 t + \pi_3(1 - e^{-\pi_4 t}) + u_t \tag{15}$$

where $(\pi_1, \pi_2, \pi_3, \pi_4)$ is a collection of meta-parameters all strictly greater than zero, and u_t is again a zero-mean error term satisfying the usual regulatory assumptions such as stationarity and normality. Notice that the regression parameters satisfy

[10] Since the structural form is directly estimated here and the model is necessarily a simplified version of reality, serially correlated and heteroskedastic errors are allowed in principle. This, in turn, necessitates the calculation of robust standard errors accordingly and the use of certain corrections on standard errors such as that of Newey and West.

$$\pi_1 = \ln\left(A_0^{\theta} n_0^{\frac{1}{\epsilon-1}}\right) \qquad \pi_2 = \theta g_A^* \qquad \pi_3 = \frac{\gamma\Delta}{\upsilon} \qquad \text{and} \qquad \pi_4 = \upsilon, \tag{16}$$

with $\gamma = \theta(g_A^* + \rho)$, and the null hypothesis of *no vertical innovation activity*, i.e., that incumbent firms do not allocate resources into in-house R & D investments, is associated with the absence of secular growth trend such that $\theta g_A^* = 0$. In other words, if the long-run growth rate is driven only by vertical innovation in theory and if vertical innovation is not active in data, then this means either of the following: First, if θ is not different from zero in a statistically significant manner, then firms must be operating with production technologies whose knowledge elasticities are close to zero. This implies that incumbent firms have no reason to invest in R & D. Second, if θ is strictly greater than zero but it is $g_A^* = 0$ that implies $\pi_2 = 0$, then firms do not invest in vertical innovation for some other reason. One such possibility is that we have

$$g_A^* = 0 \Leftrightarrow \frac{\theta(\epsilon-1)[\phi-(\rho/\alpha)]}{1-\theta(\epsilon-1)-(\rho/\beta)(\epsilon-1)} = \frac{\rho}{\alpha}, \tag{17}$$

but this is a *singularity restriction* in the language of Growiec (2007) and, thus, not a satisfactory way of explaining why the vertical innovation is inactive. A possibility free of such a singularity is the following: If α is extremely low and the cost of vertical innovation is therefore extremely high, then g_A^*, while positive, may not be different from zero in a statistically significant manner.

A final remark is related with the statistical significance of π_4. Since this parameter uniquely identifies υ, it serves as an independent (secondary) test of whether horizontal innovation is active or not.

6. Data and the Estimation Results

6.1 Data

Each of the regressions (13) and (15) requires a single time-series as its dependent variable, and time, denoted by t, enters as the only explanatory variable to each model.

For the first regression, the number of firms per capita is constructed using two sources. First, TurkStat's (2012) Table 15.1 provides data for the total numbers of newly-established and liquidated firms as flow variables at annual frequency from 1963 to 2011. The original source of data is *The Union of Chambers and Commodity Exchanges of Turkey*. Since the data for 1963 and 1964 include only joint stock and limited companies, these years are dropped from the sample, and the stock variable N_t of interest is calculated in discrete time via

$$N_t = N_{t-1} + (\text{NewlyEstablished})_t - (\text{Liquidated})_t \tag{18}$$

where an initial level N_0 of the stock is imposed for $t = 1$. Since this initial level is unfortunately unknown, several different magnitudes are experimented with to control for the dependence on the initial value. It turns out that the evolution of N_t does not really depend on the initial value when it takes values from the fairly large interval $[0,10000]$. Figure 2 pictures five alternative sequences that almost completely overlap with each other because of the dominant role of the large volumes of net increase in the number of firms; $N_0 = 1000$ is used as a plausible benchmark.

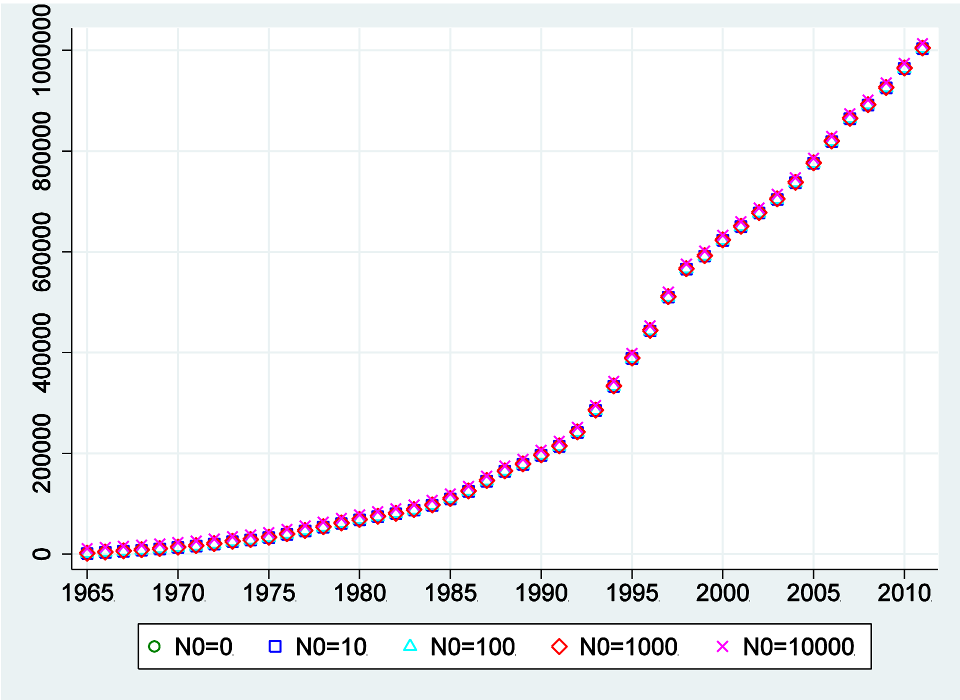

Figure 2: Alternative Constructions for the Total Number of Firms

After N_t is calculated in this way, the number of firms per capita is simply obtained by dividing N_t to the total volume of population (more specifically, to the mid-year population estimate) for each year in the sample. The time-series for annual population is readily available for the period of 1950-2011 from the PWT data of Feenstra et al. (2015).

The latter source is also utilized to obtain the time-series of aggregate TFP measures. The PWT makes available several measures of aggregate TFP. Only two of these, labeled *rtfpna* and *rwtfpna*, are appropriate to study the evolution of productivity *in time* for a single economy. Estimation results presented below are based on the use of *rwtfpna* from 1950 to 2011 since this measure is the one that goes beyond the output side and reflects the welfare adjustment that is necessary due to imported goods and services. The results, on the other hand, are quite strongly robust to the alternative use of *rtfpna*.

6.2 Estimation Results for the Number of Firms per capita

Table 1 summarizes the estimation results for n_t, Figure 3 pictures the actual and fitted values, and Table 2 summarizes the results of diagnostic tests. These indicate a very successful match of the data with the logistic form where structural parameters are statistically significant and have expected signs and magnitudes. Very simply put, the horizontal innovation channel is active in Turkey. That the residual term is normally distributed cannot be rejected, and that it contains a unit root can be rejected at 5% or 1% significance levels.

According to the estimates, the steady-state level of the number of firms per capita in Turkey, under the assumption of fixed population growth rate, is equal to $\pi_1 = n^* = 0.015788$. This implies that, in the long-run, there roughly would be 15788 firms per 1 million people in Turkey. Since the number of firms per 1 million people is equal to 13763 in 2011, it is fair to conclude that the product market in the Turkish economy is close to its limits within which entry is profitable and the Manhattan Metaphor is not binding. In other words, Turkey is approaching to a boundary point after which the technology landscape will not be enlarging faster than its population.[11]

Table 1

The Nonlinear (Logistic) Fit for $n(t)$

	NLS Estimates	**t values** *Default*	*N-W*	*Robust*
π_1	0.015	31.58***	21.91***	36.42***
π_2	0.135	23.84***	14.22***	25.04***
π_3	33.081	54.01***	36.61***	49.23***
Observations	47			
R^2	0.9970			
RMSE	0.0003			

Notes: The independent variable *t* takes values starting from 1 and running to 62. N-W t values indicate that Newey-West correction is used. Superscripts (***), (**), and (*) respectively denote statistical significance at 1%, 5%, and 10%.

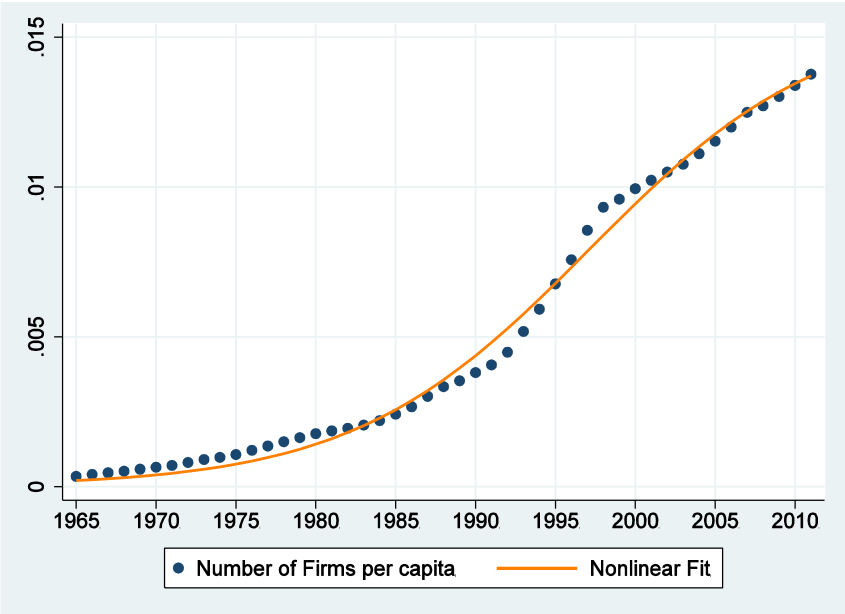

Figure 3: Actual versus Fitted Values for the Number of Firms per capita

[11] The results also indicate that, since $\pi_3 = 33.08$ identifies the inflection point of logistic law of motion and the independent variable t starts at $t = 1$ in year 1965, the number of firms per capita attains its highest growth rate in year 1997.

Table 2

Some Diagnostic Tests on the Logistic Fit for $\boldsymbol{n(t)}$

normality	*p value*	**stationarity**	*null hyp.*	*test stat.*	*lag*
kurtosis	0.5648	D-F (GLS) (μ)	unit root	−2.767***	9
skewness	0.4611	Aug. D-F (t)	unit root	−2.753***	9
joint	0.6346	Phillips-Perron (ρ)	unit root	−8.969**	3
		Phillips-Perron (t)	unit root	−2.134**	3
Observations (raw)		47			

Notes: The tests report the diagnostic results for the residual term of the logistic fit for $n(t)$. The normality test is the Jarque-Bera type test proposed by D'Agostino et al. (1990), and the reported results use Royston's (1991) empirical correction. The null hypotheses are of normality in all cases. D-F and GLS respectively stand for Dickey and Fuller and Generalized Least Squares. Lags are chosen optimally for D-F (GLS) and Phillips-Perron tests using Ng-Perron and Newey-West criteria respectively. The maximum number of lags experimented with in D-F (GLS) is chosen according to the Schwert criterion. Superscripts (***), (**), and (*) respectively denote statistical significance at 1%, 5%, and 10%.

6.3 Estimation Results for Aggregate TFP

Table 3, Figure 4, and Table 4 respectively show parameter estimates, actual versus fitted values, and diagnostic test results for aggregate TFP. Parameters other than π_2 which determines the secular component of TFP are statistically significant, and, once again, the residual term satisfies normality and stationary assumptions as dictated by diagnostic tests.

That π_2 is not statistically significantly different from zero is the central result of interest here; it is the most important piece of evidence indicating that the vertical innovation does not work in Turkey. As discussed in the previous section, $\pi_2 = \theta g_A^* = 0$ implies either $g_A^* = 0$ or $\theta = 0$. This is a problem of identification, and the answer to which one is the case follows from the evaluation of other parameters. Notice that, from a statistical point of view, we have $\pi_4 = \upsilon > 0$.[12] It is also true that $\Delta = (n^*/n_0) - 1$ is positive as the above results suggest. Finally, since $\pi_3 = (\gamma\Delta)/\upsilon > 0$ is also established statistically, γ must be strictly positive. Recall that this parameter satisfies $\gamma = \theta(g_A^* + \rho)$, and this now implies that $\theta > 0$ and $g_A^* = 0$. In statistical language, the null hypothesis of no vertical innovation cannot be rejected. In English, the vertical innovation channel is not active in Turkey.

[12] That this parameter is statistically significantly different from zero and strictly positive shows that the null hypothesis of no horizontal innovation can be rejected using aggregate TFP data as well. Thus, we have not one but two confirmations of why the horizontal innovation is active in Turkey.

Table 3

The Nonlinear Fit for ln$[TFP_t]$

	NLS Estimates	t values *Default*	*N-W*	*Robust*
π_1	−0.6685	−8.07***	−23.95***	−8.91***
π_2	−0.0007	−1.14	−1.27	−1.06
π_3	0.6168	7.95***	38.47***	8.92***
π_4	0.2377	4.55***	7.60***	4.56***
Observations	62			
R^2	0.6587			
RMSE	0.0613			

Notes: The independent variable *t* takes values starting from 1 and running to 62. N-W t values indicate that Newey-West correction is used. Superscripts (***), (**), and (*) respectively denote statistical significance at 1%, 5%, and 10%.

Recalling the discussion in the previous section, we can actually offer more about the structural parameters. Since we have now a confirmation for $\theta > 0$, what explains $g_A^* = 0$ is either a very low level of knowledge elasticity θ or a very low level of process innovation productivity α (or both). These imply that, if singularity restrictions are avoided as causal explanations, either a large portion of useful knowledge that can be generated using process innovations is not really relevant for actual needs of production processes or, even if it is, firms face a large enough process innovation cost due to low productivity of R & D technology so that they choose to not to invest in new processes. Intuition suggests that the reality for Turkey is in between these two points: The low-θ situation in manufacturing industries would not be a surprise given that Turkey does not export high-tech products, and low-α situation would be consistent with a labor force that lacks skills and expertise necessary for successful and sustained innovation (see, e.g., Taymaz, 2001; Şenses and Taymaz, 2003; Yolcu Karadam and Özmen, 2015). Besides, studies using firm-level data from Turkey document that exporting is positively related with process innovation successes (Özçelik and Taymaz, 2004) and skill upgrading (Meschi et al., 2011).

One last remark concerns the shape of the transition path for ln$[TFP_t]$. The estimation results imply that ln$[TFP_t]$ converges to a constant for $t \to +\infty$. As very clearly seen in Figure 4, the transitory components converge to constants, and $g^* = 0$ does not allow us to observe a sequence of ln$[TFP_t]$ that increases as a linear function of time. Put differently, if a process innovation reform in Turkey will not be successfully implemented in the near future, aggregate TFP will not exhibit (exponential) growth.

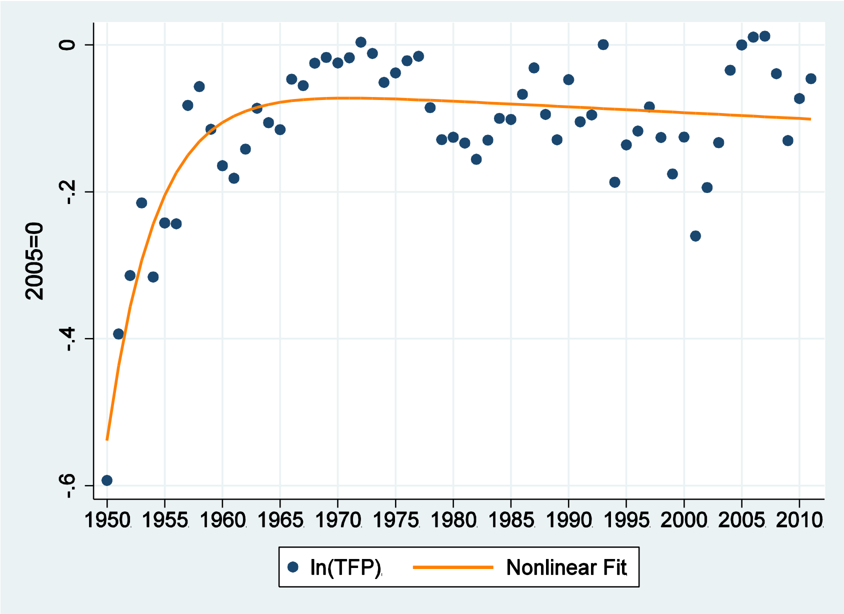

Figure 4: Actual versus Fitted Values for Aggregate TFP

Table 4

Some Diagnostic Tests on the Nonlinear for $\ln[TFP_t]$

normality	*p value*	**stationarity**	*null hyp.*	*test stat.*	*lag*
kurtosis	0.4335	D-F (GLS) (μ)	unit root	-2.120^{**}	7
skewness	0.4657	Aug. D-F (t)	unit root	-3.246^{***}	7
joint	0.5527	Phillips-Perron (ρ)	unit root	-31.216^{***}	3
		Phillips-Perron (t)	unit root	-4.475^{***}	3
Observations (raw)		62			

Notes: The tests report the diagnostic results for the residual term of the nonlinear fit for $TFP(t)$. The normality test is the Jarque-Bera type test proposed by D'Agostino et al. (1990), and the reported results use Royston's (1991) empirical correction. The null hypotheses are of normality in all cases. D-F and GLS respectively stand for Dickey and Fuller and Generalized Least Squares. Lags are chosen optimally for D-F (GLS) and Phillips-Perron tests using Ng-Perron and Newey-West criteria respectively. The maximum number of lags experimented with in D-F (GLS) is chosen according to the Schwert criterion. Superscripts (***), (**), and (*) respectively denote statistical significance at 1%, 5%, and 10%.

7. Summary and Discussion

What do we know about the long-run patterns of economic growth in Turkey? What are the mechanisms that at least partially determine how economic growth occurs? Which engines do operate and increase aggregate TFP? Why are some other growth engines not working for the Turkish economy?

This paper offers new and concrete answers to these questions. The analysis takes the Schumpeterian paradigm seriously and utilizes Peretto and Connolly's (2007) second-generation model. This model has sound microeconomic foundations and robust theoretical properties. It also attains a closed-form solution for its unique general equilibrium, and key endogenous variables of the model have reduced-form representations that allow us to estimate some of the structural parameters in a rigorous manner.

The nonlinear regressions estimated test for horizontal and vertical dimensions of innovation using time-series data. The nonlinear regression estimates of the closed-form solutions indicate that, in Turkey, the horizontal innovation is active but the vertical innovation is not. In other words, the two-dimensional technology landscape of the economy expands in only one direction in Turkey.

That the vertical innovation is not active is directly related with the question of why the Turkish economy did fail to converge to frontier economies. Unlike economies such as Japan, South Korea, and China, Turkey was not really successful in sustaining intensive growth episodes for more than a decade or so in the second-half of the 20th century. If the rate at which the technology landscape in its vertical dimension expands was sufficiently high even if it is constant, the relative underperformance of the Turkish economy would definitely be less severe and real GDP per capita differences between Turkey and frontier economies would be much lower.

Three noteworthy aspects of these results are the following: First, they do not carry any endogeneity bias; directly estimating the reduced-form solutions identifies the structural parameters. Second, results advance our understanding of how the Turkish economy really evolves and exactly why it does not grow in a really fast manner in the very long run. Finally, since the results clearly determine which type of innovation channel does not work in Turkey, they in principle lead the way to the formation of appropriate industrial and technological policies. While it is not always straightforward to design a "first best" policy due to various types of heterogeneities across firms and complementarities across policy options (Ferragina et al., 2014), one macro policy message is immediate here: Since the profitable operation of the vertical innovation necessitates a sufficiently large firm size in the second-generation Schumpeterian models (Peretto, 2016) and since surviving firms have considerably larger sizes in Turkey (Pamukcu et al., 2010), it is quite clear that the creation of firms, i.e., entry, is of secondary importance for a fixed policy budget. Efforts, instead, should be exerted to let the incumbent firms grow before they are forced to leave the market for some reason such as credit constraints or economic crises. This policy message is largely consistent with the one offered by Özçelik and Taymaz (2004) on the appropriateness of in-house R & D subsidies in Turkey. Since these authors arrive at this conclusion using micro-data for Turkish manufacturing firms, the present paper that utilizes macro-data for Turkey and reaches a similar conclusion is highly complementary.[13]

[13] Two further things should be noted: First, in comparison with other OECD countries, the total amount of resources spent on R & D as a share of GDP is considerably low in Turkey. Second, Taymaz and Üçdoğruk's (2013) estimates based on a panel of Turkish firms indicate that R & D support programs positively affect the labor demand for researchers. Therefore, increasing the total amount of resources directed to R & D support programs is an appropriate policy option regardless of whether entrant firms obtain a bigger share of financial supports or not. See Özçelik and Taymaz (2008) and Yılmaz and Yıldırım (2013) for more micro-econometric evidence substantiating this view for Turkey.

8. Conclusion

Much remains to be done to complete a satisfactory analysis of economic growth and development in Turkey. The literature has so far been illuminating in accounting for the proximate sources of growth and some of the likely reasons behind the relatively poor growth performance of the Turkish economy. But answers to challenging questions in economics can usually be iterated toward more challenging questions. If business firms in Turkey do not generally have a large enough firm size to profitably invest in process innovations, why is this the case? Exactly for which reason do these firms not expand in size even though the number of firms keeps increasing in the extensive margin of entry? The demand and supply mechanisms determining the equilibrium size of firms enter this picture in quite transparent ways in theory, but identifying the structural mechanisms is not always feasible given the limited availability and quality of micro data. And even if one can ever decipher the demand- or supply-side *factor x* that is explanatory here, there would still be another iteration: Is it the lack of good policy or too much of regulation and bureaucracy causing *factor x*? Is it more fundamentally about how economic and political institutions emerge and evolve? What about the role of culture in affecting all of these? These are questions that would consume a decade of research if not a lifetime of it, and the field is wide open for future work quite specifically guided by truly Schumpeterian notions.

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