

Economic growth and technological progress in Turkey: An analysis of Schumpeterian mechanisms¹

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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 both horizontal (product) and vertical (process) innovation channels operate as determined in theory. However, the pace at which vertical (process) innovation occurs is extremely low, implying that its contribution to long-run productivity growth is severely limited. Since the paper directly estimates the structural forms originating from the general equilibrium of the model economy, results do not carry any endogeneity bias. That the technological landscape very slowly expands in its vertical dimension explains why the Turkish economy did not converge to frontier economies. Since whether a firm should engage in vertical (process) innovation crucially depends on its size in theory, the most appropriate policy under resource constraints may be to strengthen the incumbent firms and support their growth. Put differently, the formation of new enterprises in the horizontal dimension may not be a policy priority.

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

JEL classification codes: O32, O41, O50.

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*

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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).² 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 slightly less than 3% (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 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; İmrohoroglu 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; Attar, 2013; 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 second-generation Schumpeterian models also solve the scale effect problem of the first-generation models of Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992). In these first-generation models, entrepreneurs and business firms deliberately allocate resources into innovative activities in search of higher market shares and higher profits. Economic growth becomes fully endogenous and policy-variant through research subsidies and other

² The German original of this work by Schumpeter was published in 1911.

means. Jones (1995a) however shows that these models' prediction of an increasing long-run growth rate given an increasing number of R&D personnel sharply contradicts with postwar experience of the US economy. Some theorists including Jones (1995b) and Kortum (1997) look 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. But this results in long-run growth rate being semi-endogenous and largely policy-invariant. In the second-generation models, theorists insist 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.

This 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) and the Union of Chambers and Commodity Exchanges of Turkey (TOBB, 2017) confirm that, from 1965 to 2016, 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 factor productivity (TFP) as well. As in the case of the number of firms per capita, the nonlinear least squares fit for aggregate TFP that uses the Penn World Tables (PWT) data provided by Feenstra et al. (2015) is considerably well for the period from 1950 to 2014. However, these estimates also show that the contribution of Schumpeterian vertical innovation to the long-run (secular component of) aggregate productivity growth is remarkably low in Turkey.

This paper contributes to the literature by rigorously showing that the technology landscape of the Turkish economy expands in its horizontal and vertical dimensions. However, it also shows that the pace at which vertical innovation occurs is extremely low. Four aspects of the present analysis are worth emphasizing

to clarify the contribution of this paper: First, since the paper estimates the structural forms directly and identifies structural parameters, results do not carry an endogeneity bias. Second, the result showing that the contribution of vertical innovation to aggregate productivity growth is quite limited 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). Third, thanks to the identification of some structural parameters indicating that the pace at which vertical innovation occurs remains very low in the long run, 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. Finally, the paper also contributes to the literature that investigates the empirical validity of (second-generation) Schumpeterian models, firstly, by estimating a rich general equilibrium model's reduced-form equations and, secondly, by implementing these estimations with a developing country's dataset. Other than Laincz and Peretto (2006) who provide evidence on the validity of second-generation models, Ha and Howitt (2007), Madsen (2008), Madsen et al. (2010), Ang and Madsen (2011), and Venturini (2012) derive their estimating equations directly from the theory, use aggregate time-series data, and find that the experience of different countries in different time frames are best explained by second-generation Schumpeterian models that sterilize the scale effects. These studies, however, estimate empirical models that are linear in parameters and use explanatory variables that remain endogenous in theory. This paper contributes to the literature by directly estimating the nonlinear, reduced form specifications where the drivers of long-run economic growth are expressed as functions only of time. The estimates are thus robust against measurement errors and endogeneity problems that may contaminate results when other explanatory variables are present.³

Section 2 briefly surveys the literature on economic growth and productivity in Turkey. Section 3 presents the theoretical analysis in two subsections. Subsection 3.1 introduces how various second-generation Schumpeterian models construct the technology landscape of an economy with product and process innovations. Subsection 3.2 then builds upon Peretto and Connolly's (2007) model specifically and derives the mathematical equations to be estimated. Section 4 describes data

³ Of these papers, Ang and Madsen's (2011) tests the validity of Schumpeterian models for China, India, Japan, Singapore, South Korea, and Taiwan by using annual data running from 1953 to 2006. Results following from a diversity of methods strongly support the theoretical predictions of second-generation Schumpeterian models.

and presents the main estimation results. Section 5 discusses these results and concludes the paper with some remarks.

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 around 2.85% 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 around 2.95% from 1950 to 2014.

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. Table 1 summarizes postwar growth rates in selected economies. 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, Atıyas and Bakış (2014) provide growth-accounting results showing that TFP growth is significant especially in 2000s and especially in agriculture. Üngör and Kalafatçılar (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.

Table 1

Postwar Growth Rates in Selected Economies (% per annum)				
	1950-59	1960-69	1970-79	1980-89
Turkey	5.23	3.40	2.11	2.71
Hong Kong		5.75	5.89	5.01
Singapore		10.09	9.76	1.27
South Korea	2.38	5.88	11.25	9.15
Taiwan	4.66	6.30	8.34	7.22
Japan	6.47	9.09	4.86	3.29
China	4.25	0.18	2.38	4.59
Germany	7.80	3.41	3.60	1.98
UK	2.20	2.36	3.05	1.91
USA	1.90	3.37	2.71	2.37
	1990-99	2000-09	2010-14	1950-2014
Turkey	0.67	2.55	4.94	2.95
Hong Kong	1.57	1.81	1.97	4.22
Singapore	0.76	3.03	3.17	6.15
South Korea	6.02	3.09	2.37	5.92
Taiwan	4.82	0.73	2.79	5.30
Japan	2.02	-0.05	0.03	4.22
China	5.55	8.73	7.44	4.34
Germany	2.84	1.86	3.24	3.67
UK	3.17	0.26	2.79	2.23
USA	2.31	0.53	1.37	2.00

Notes: The data source for this table is Feenstra et al. (2015). Entries indicate average, annual, percentage growth rates of real GDP per capita in purchasing power parity corrected terms. For China, South Korea, and Taiwan, available data start respectively at 1952, 1953, and 1951.

Three papers that complement these studies via models with microeconomic foundations are those of Adamopoulos and Akyol (2009), Çiçek and Elgin (2011), and İmrohoroglu 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.⁴ 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

⁴ A recent study by Atesagaoglu et al. (2017) develops a growth model with formal and informal sectors for Turkey and uses this model to filter out TFP measures. They find that ignoring the presence of informality leads to the underestimation of TFP especially after 1980s.

low has not been subjected to structural econometric evaluation before. This is precisely what this paper is after.

3. The model

3.1. 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 productivity levels associated with products.

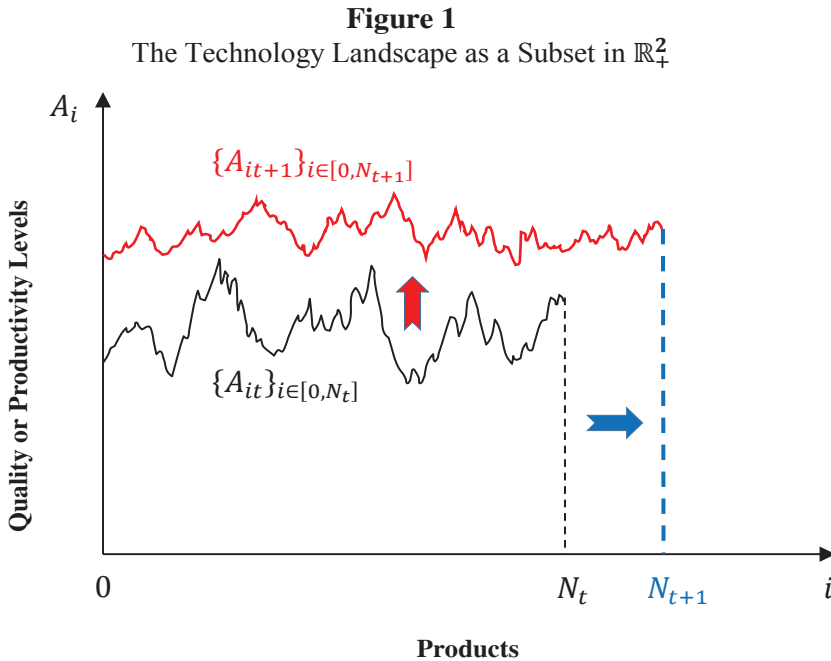


Figure 1 pictures a typical two-dimensional technology landscape for an economy operating in discrete time t .⁵ An index variable i is on the horizontal axis, satisfying $i \in [0, N_t]$ where N_t denotes the number of products in use at time t . $A_i > 0$ on the vertical axis indicates the level of 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

$$\int_0^{N_t} A_{it} di. \quad (1)$$

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.

3.1.1. 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

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

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

⁵ Nothing essential would be different or lost if a continuous-time framework is adopted to introduce the same notions.

3.1.2. 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

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

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.

3.2. Tests of the Schumpeterian mechanisms

This section describes two tests of Schumpeterian mechanisms. To proceed with clarity, however, a brief but more specific introduction of the underlying theory is essential and now in order.⁶

3.2.1. 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 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.⁷ 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

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

⁶ The theoretical discussion here necessarily omits certain less central parts of the underlying theory for space considerations.

⁷ 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).

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

$$X_i = A_i^\theta (L_{X_i} - \phi) \quad (5)$$

where L_{X_i} is the flow of labor employed for the production of good i and $\phi > 0$ is the fixed operating cost.⁸ 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.⁹

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

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

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

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

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

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

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

⁸ 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.

⁹ 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.

innovation, and $\rho > 0$ is the familiar subjective discount rate that discounts utility flows exponentially via $e^{-\rho t}$.¹⁰

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 $t \rightarrow +\infty$.¹¹ 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

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

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^{-vt} .

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

$$g^* = \omega g_N^* + \theta g_A^* \quad (10)$$

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 $TFP(t)$ both converge to zero for $t \rightarrow +\infty$. How exactly this

¹⁰ 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).

¹¹ In other words, the growth rate of the logistic variable is a bell-shaped function of time.

convergence occurs, on the other hand, carries information about the structural parameters of the model through the meta-parameters γ , Δ , and v . We have

$$\gamma = \theta(g_A^* + \rho) \quad (11)$$

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:

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

3.2.2. 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

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

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

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

and u_t is a zero-mean error term which is distributed as a normal variable and is stationary.¹²

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.

3.2.3. 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

¹² 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.

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

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

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

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

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

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 v , it serves as an independent (secondary) test of whether horizontal innovation is active or not.

4. Data and the estimation results

4.1. 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.

Table 2
The Flow Numbers of Firm Entry and Exit in Turkey

	Newly Established	Liquidated
1965	1950	1020
1970	3860	1094
1975	5303	772
1980	7527	182
1985	13917	981
1990	18699	644
1995	56046	595
2000	33161	1887
2005	47401	8886
2010	51971	13442
2011	54442	14991
2012	39764	16063
2013	49943	17400
2014	58715	15822
2015	67622	13701
2016	64481	12328

Notes: The data source is TurkStat (2012) for 1965-2010 and TOBB (2017) for 2011-2016.

For the first regression, the number of firms per capita is constructed as follows. 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* (TOBB) that publishes this data now officially. The data for the total numbers of newly-established and liquidated firms after 2011 have thus been obtained from TOBB (2017). Table 2 presents a summary of flow numbers of entering and exiting firms for some selected years.

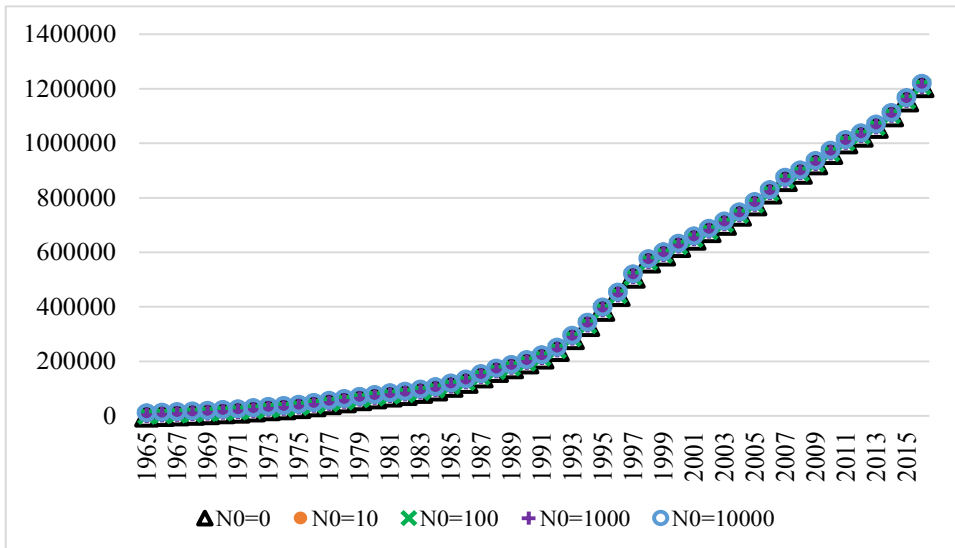
Since the data for 1963 and 1964 include only joint stock and limited companies, these years are dropped from the sample, and the stock variable N_t of interest, the total number of firms, is calculated in discrete time via

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

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 mid-year population estimates are obtained from TurkStat (2017).

The time-series of aggregate TFP measures are available from the PWT data of Feenstra et al. (2015). The PWT makes available several measures of aggregate TFP, but only two of these, labeled *rtfpna* and *rwtfpna*, are appropriate to study the evolution of productivity *in time* for a single economy.¹³ Estimation results

¹³ Real GDP and TFP measurements in the PWT follow from a methodology that overcomes the difficulty of comparing real GDP and TFP across countries for a given year and across time for a given country. As extensively discussed by Feenstra et al. (2015), authors first construct price indexes for consumption, investment, government expenditures, imports, and exports under the assumptions that product and factor markets are perfectly competitive, outputs are revenue-maximizing, revenue functions are well-defined, Hotelling's Lemma applies, and the law one price holds. They then use the Geary-Khamis methodology to obtain reference prices for each year as these common reference prices can be used to obtain real GDP growth rates by substituting optimal quantities with observed ones. To

presented below are based on the use of *rwtfpna* from 1950 to 2014 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*.¹⁴

4.2. Estimation results for the number of firms per capita

Table 3 summarizes the estimation results for n_t , Figure 3 pictures the actual and fitted values, and Table 4 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.¹⁵ 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 $\pi_1 = n^* = 0.015684$. This implies that, in the long-run, there roughly would be 15684 firms per 1 million people in Turkey. Since the number of firms per 1 million people is roughly equal to 15157 in 2016, it is fair to conclude that the product market in the Turkish economy is extremely 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.¹⁶

obtain TFP measures, authors build upon the index number theory that guarantees the identification of Harrod-neutral TFP terms under the assumption that, for two countries, the revenue functions are both of translog form with same second-order parameters across countries. They then use real GDP, real capital stock, labor input, and the time-variant labor share to obtain the unobserved TFP measure.

¹⁴ The use of welfare-relevant TFP *rwtfpna* is preferred because it takes into account the prices consumers face, and this price set includes the prices of imported goods. It therefore goes beyond the output prices. A paper by Ferreria and Trejos (2011) documents that TFP effects of gains from trade are indeed sizable. For a theoretical discussion on the welfare-relevant TFP, see Basu et al. (2016).

¹⁵ Estimation results presented in the next subsection also show that ν is positive and statistically significant. This 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. Furthermore, a simple t test cannot reject the null hypothesis that the two alternative values of ν are equal. When the robust standard errors are used, the t statistic is equal to 1.29.

¹⁶ The results also indicate that, since $\pi_3 = 33.69$ 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 3
The Nonlinear (Logistic) Fit for $n(t)$

	NLS	t values		
	Estimates	Default	N-W	Robust
π_1	0.015	57.01***	65.05***	50.55***
π_2	0.140	31.71***	30.67***	32.03***
π_3	33.691	91.73***	97.74***	69.73***
Observations	52			
R^2	0.9981			
RMSE	0.0003			

Notes: The independent variable t takes values starting from 1 and running to 52. 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

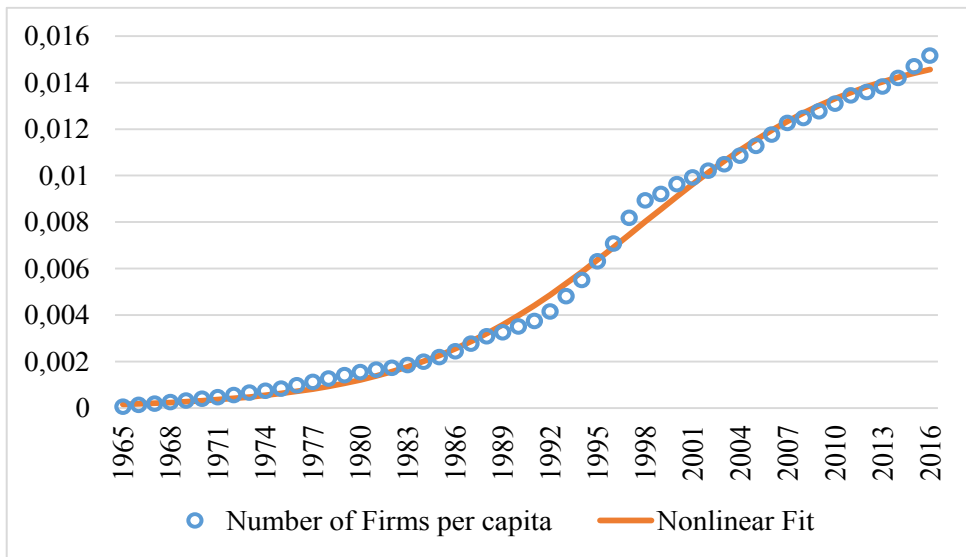


Table 4
Some Diagnostic Tests on the Logistic Fit for $n(t)$

normality	<i>p value</i>	stationarity	<i>null hyp.</i>	<i>test stat.</i>	<i>lag</i>
kurtosis	0.3348	D-F (GLS) (μ)	unit root	-4.188***	9
skewness	0.3949	Aug. D-F (t)	unit root	-4.182***	9
joint	0.4203	Phillips-Perron (ρ)	unit root	-11.633**	3
		Phillips-Perron (t)	unit root	-2.263**	3
Observations (raw)		52			

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%.

4.3. Estimation results for aggregate TFP

Table 5, Figure 4, and Table 6 respectively show parameter estimates, actual versus fitted values, and diagnostic test results for aggregate TFP. All of the structural parameter estimates are statistically significant, and, once again, the residual term satisfies normality and stationary assumptions as dictated by diagnostic tests.

That π_2 is statistically significantly different from zero but is still very close to it is the central result of interest here; it simply indicates that the vertical innovation channel, while active from the viewpoint of statistical significance, does not create an economically significant contribution to long-run productivity growth in Turkey. Following up from the discussion in the previous section, $\pi_2 = \theta g_A^* > 0$ implies $g_A^* > 0$ and $\theta > 0$.¹⁷ But the point estimate of $\pi_2 = 0.0021$ also implies that either the knowledge elasticity θ or the growth rate g_A^* are sufficiently small. For instance, if we have $\theta = 0.5$, then $\pi_2 = 0.0021$ implies that $g_A^* = 0.42\%$ per annum. For $\theta = 0.25$, g_A^* rises only to 0.84% per annum.

¹⁷ That $\theta > 0$ also follows from the identification of other structural parameters: Notice that we have $\pi_4 = v > 0$. It is also true that $\Delta = (n^*/n_0) - 1$ is positive as the above results suggest. Finally, since $\pi_3 = (\gamma\Delta)/v > 0$ is also established statistically, γ must be strictly positive. Recall that this parameter satisfies $\gamma = \theta(g_A^* + \rho)$, and this now implies that $\theta > 0$.

Table 5
The Nonlinear Fit for $\ln[TFP_t]$

	NLS	t values		
	Estimates	Default	N-W	Robust
π_1	-0.9707	-19.15***	-49.04***	-15.96***
π_2	0.0021	2.03**	3.11***	2.18**
π_3	0.7964	14.43***	29.27***	14.19***
π_4	0.1137	6.02***	9.91***	5.71***
Observations	65			
R^2	0.9235			
RMSE	0.0580			

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%.

The role of the knowledge elasticity $\theta \in (0,1)$ is more complicated than what $\pi_2 = \theta g_A^*$ suggests. Together with a very low level of process innovation productivity $\alpha > 0$, a very low level of knowledge elasticity θ also explains a sufficiently low level of the growth rate g_A^* . Thus, either a large portion of useful knowledge that can be generated using process innovations is not really relevant for actual needs of production processes (low- θ) 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 large amount of resources in new processes (low- α). 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).

These estimation results imply that $\ln[TFP_t]$ converges to a balanced growth path for $t \rightarrow +\infty$. The balanced growth rate directly following from the point estimate of π_2 is $g^* = 0.21\%$ per annum. This balanced growth rate is alarmingly low, clarifying the urgent need of some sort of a process innovation reform in Turkey. It is important to note that directly estimating the structural form originating from the dynamic general equilibrium of the model to understand the long-run evolution of aggregate TFP is methodologically superior to naive OLS results following from the regression $\ln[TFP_t] = \pi_1 + \pi_2 t + u_t$; such an OLS estimation returns a balanced growth rate estimate that is about 4 times larger than what our structural NLS estimation suggests.

Figure 4
Actual versus Fitted Values for Aggregate TFP

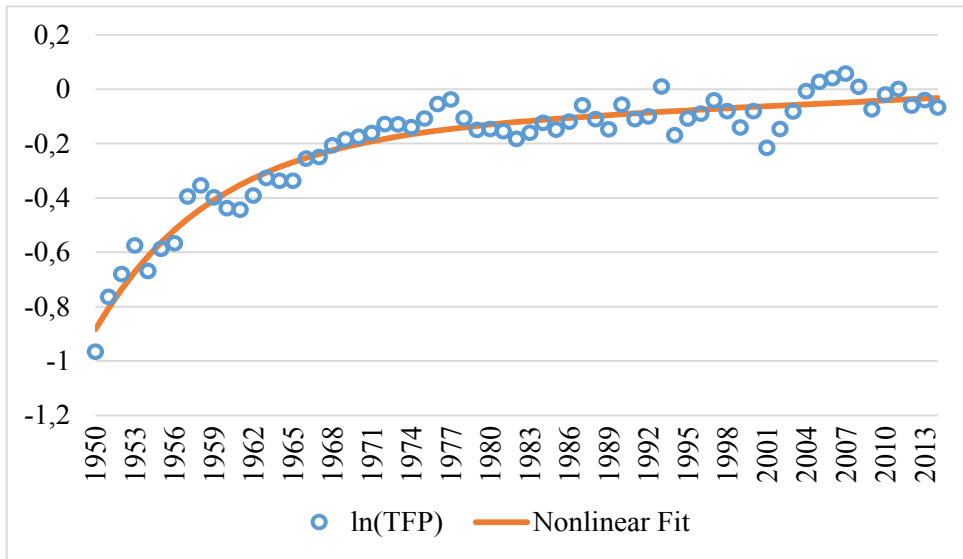


Table 6
Some Diagnostic Tests on the Nonlinear for $\ln[TFP_t]$

normality	<i>p value</i>	stationarity	null hyp.	test stat.	lag
kurtosis	0.6547	D-F (GLS) (μ)	unit root	−3.596***	0
skewness	0.9861	Aug. D-F (<i>t</i>)	unit root	−5.076***	0
joint	0.9047	Phillips-Perron (ρ)	unit root	−38.638***	3
		Phillips-Perron (<i>t</i>)	unit root	−5.174***	3
Observations (raw)		65			

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%.

5. Discussion and concluding remarks

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, both dimensions of innovation, i.e., horizontal and vertical, are active. In other words, the two-dimensional technology landscape of the economy expands in both directions in Turkey.

That both types of innovative activity are statistically significant sources of technological progress is in line with TurkStat's Innovation Surveys that target certain industry and services sectors; large fractions of firms from industry and services sectors report themselves as innovators (TurkStat, 2017). The latest data for 2012-2014 indicate that 51.3% of firms are innovative enterprises. When the firm size measured by the number of employees is considered, larger firms are more innovative for all types of innovations as expected. Regarding the type of innovation, 22.7% and 26.8% of all the respondent firms are respectively product and process innovators. Besides, these figures do not exhibit much variation in time with similar fractions being tabulated for 2010-2012, 2008-2010, and 2008-2006 waves of the survey.

That the vertical innovations' contribution to long-run productivity growth remains low 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.¹⁸ 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.

This paper contributes to the literature focusing on the empirical applications of Schumpeterian models as discussed in the Introduction. Three noteworthy

¹⁸ That intensive growth episodes were usually shorter in Turkey is not trivial since the cyclical component of the TFP term exhibits sizable downturns mostly synchronized with bust episodes of the business cycles as observed in Figure 4. These bust episodes for TFP include 1958-60, 1977-79, 1993-94, 1997-99, 2000-01, and 2007-09. During these episodes, the number of newly established firms usually decreases and the number of liquidated firms usually increases. However, these do not create sizable effects on the (stock) number of firms per capita as shown in Figure 3.

aspects other than this are the following: First, results 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. Third, results 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.¹⁹

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 sufficiently large amounts 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

¹⁹ 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.

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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Özet

Türkiye’de iktisadi büyüme ve teknolojik gelişme: Schumpetergil mekanizmaların bir çözümlemesi

Bu makale, Türkiye’de teknolojik gelişme ve iktisadi büyümenin doğasını anlamak için, ikinci-nesil bir Schumpetergil model çalışmaktadır. Makale bazı yapısal parametreleri nümerik olarak belirlemekte ve Schumpetergil mekanizmaların işleyip işlemediğini sınamaktadır. Sonuçlar, hem yatay (ürün), hem de dikey (süreç) yeniliği kanallarının kuramda belirlendiği gibi işlediğini göstermektedir. Ancak, dikey (süreç) yeniliği, aşırı ölçüde düşük bir hızda gerçekleşmekte olup, bunun uzun-dönem verimlilik büyümesine katkısı ciddi şekilde sınırlıdır. Makale, model ekonominin genel dengesinden türeyen yapısal biçimleri dolaysız olarak tahmin ettiği için, sonuçlar herhangi bir içsellik sapması taşımamaktadır. Teknoloji alanının dikey boyutta çok yavaş genişlemesi, Türkiye ekonomisinin neden ileri ülkelere yakınsamadığını açıklamaktadır. Kuramda bir firmanın dikey (süreç) yeniliği yapmasının gerekli olup olmadığı firmanın büyüklüğüne hayati biçimde bağlı olduğu için, kaynak kısıtları altında en uygun politika, yerleşik firmaları güçlendirmek ve bunların büyümesini desteklemek olabilir. Bir başka deyişle, yatay boyutta yeni girişimlerin kurulması, bir politika önceliği olmayabilir.

Anahtar kelimeler: Ar-Ge, piyasaya giriş, süreç yeniliği, ürün yeniliği, verimlilik, politika

JEL kodları: O32, O41, O50.