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The effect of innovation on productivity: evidence from Turkish manufacturing firms

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ABSTRACT

This paper systematically explores the effects of firms' innovation activities on their productivity changes for Turkish manufacturing firms, differentiating between different typologies of innovation. We employ endogenous switching methodology, controlling for endogeneity and selection bias issues, as well as analysing counterfactual scenarios. The main finding of the study points to firm heterogeneity in terms of propensity both to innovate and to benefit from innovation activities. Our results indicate that all types of innovation activity have positive effects on the productivity of firms when compared with non-innovating firms. We find robust evidence for the differential impact of innovation on firm productivity across different innovation types. Further, this relationship alters across different phases of the economy with respect to the 2008 financial crisis.

KEYWORDS
Innovation; productivity; economic crisis

SUBJECT CLASSIFICATION CODES
D22; L25; O30

1. Introduction

Early studies in development claim that economic growth in many countries can be partly explained by growth in capital and labour. The remainder is attributed to the 'Solow residual', after the seminal work of Solow (1957), which is interpreted as a measure of productivity growth. Since then, an extensive literature has developed attempting to explain this residual using technical change. However, this approach still lacks a full explanation of productivity growth, as information on innovation is not employed. Driven by these facts, complementary research emerged to investigate the linkage between innovation activity and productivity. Although the relevant literature handled the issue at the aggregate or industry level, the innovation-making decision units are firms. Further, as innovation is the search for the adoption and commercialisation of new processes, products, and organisational structures, it entails uncertainty. Accordingly, innovation itself and its effects on productivity can be heterogeneous among firms. Thus, to examine the innovation and productivity nexus, firms should be taken as the unit of observation.

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Far from being a concern of advanced countries alone, benefits from innovative efforts in terms of firm performance gain importance especially for developing regions of the world, as innovation activity is costly for such countries, due to their scarce resources of technology and human capital. Motivated by these facts, this paper systematically investigates the effects of firms' innovation activities on their productivity changes for Turkish manufacturing firms. To accomplish this, we use a comprehensive data-set on the innovation activities of firms in Turkey; in so doing, we aim to expand the limited literature on developing countries.

Hall (2011) suggests that innovation efforts can translate into productivity gains for firms, such that innovations can both increase firms' efficiency and improve the products they offer, hence escalating demand and reducing the costs of production. There exists contradictory evidence about gains from innovation in terms of firm performance, with the empirical evidence on this relationship varying among types of firms and measurements of productivity, as well as across different types of innovation. Although there is much less evidence regarding the negative effects of innovation on productivity when compared with studies reporting positive findings, this conflicting evidence indicates that there are still unidentified issues regarding the innovation and productivity nexus.

Results regarding linkages between innovation and firm performance are generally put forward on the basis of normal economic conditions, without considering business cycles. Accordingly, another strand of studies explores the impact of the 2008 economic downturn on the innovative activities of firms (Hud and Hussinger 2015; Teplykh 2017). While being exposed to crisis may create significant shifts in the innovative behaviour of firms, the ability of firms to transform their innovative activity into productivity gains may also change (Castellani et al. 2016).

In this paper, we conjecture that different typologies of innovation play different roles in firm performance. Thus, adopting an input-output approach, we dissect the effects of innovative inputs (internal R&D and embodied technical change, external R&D and disembodied technical change) as well as outputs of innovation (product, process, and organisational). Further, we distinguish between two different types of product innovation, in which a product new to the market is considered as radical and a product new to the firm is perceived as only incremental.

Building on the micro-econometric literature, which focuses on the relationship between innovation and productivity, we also ask a novel question for Turkish manufacturing firms and examine the changes in the relationship between innovation and productivity with respect to the worldwide 2008 economic crisis. We argue that the business cycle is a key determinant of this observed empirical relationship and that the productivity premium innovators experience in the pre-crisis period is larger than the premium they experience in the post-crisis era. The pre-crisis period is characterised by a comparatively friendly environment in terms of both demand and external financing conditions, in which firms are more likely to achieve productivity improvements from innovation. Turkey, which was seriously hit by the crisis, is an interesting case given the sharp contraction in its the real sector activity due to the collapse in both external and domestic demand.

Our evidence is based on a recent and comprehensive firm level data-set for Turkish manufacturing firms over the period 2003–2012, mainly constructed on the four consecutive waves of the 'Community Innovation Surveys', that is, 2006, 2008, 2010, and 2012. In order to conduct our analyses on the innovation-productivity relationship for Turkish firms, we utilise an endogenous switching technique, allowing us to exploit the richness of our data-set, while controlling for endogeneity and selection bias issues as well as analysing counterfactual scenarios.

Our contribution to the relevant literature on the innovation-productivity nexus is fourfold. First of all, we present a comprehensive analysis of the association between productivity and innovation, dissecting various innovation indicators, as well as taking an input-output approach to different innovation modes. To the best of our knowledge, this study is the first attempt to explore the effect of innovation on productivity for Turkish firms, using non-traditional proxies for innovation (except for R&D expenditures) via the analysis of differential impacts of different types of innovations.

Second, both economic intuition and stylised facts suggest that different modes of innovation are endogenous and that endogeneity exists between all modes of innovation and firms' future productivity performance. In contrast with most studies in this field, we control for endogeneity that might occur between different typologies of innovation by creating instruments to capture other efforts the firm is undertaking in terms of innovations. Next, using a novel approach, we investigate how the recent global crisis of 2008 altered the relationship between innovation and firm productivity in Turkey. We thereby shed light on the effect of Turkish firms' innovation activities on their productivity for this particular period, which has not been examined by previous studies. Our final contribution stems from our methodology of endogenous switching, which further allows us to examine counterfactual scenarios. This technique is helpful in distinguishing between cases where innovating firms experience productivity gains or losses from innovation; but also where non-innovating firms experience productivity gains or losses from non-innovating, the latter scenario being largely neglected in the literature.

The remainder of this paper is organised as follows. Section 2 gives brief information on the background literature. Section 3 introduces the data and Section 4 describes methodology of the study. Section 5 presents the results of our empirical investigation. Section 6 concludes.

2. Background literature

Modern innovation surveys mostly rely on the Oslo Manual (OECD 1992, 1996, 2005), providing guidelines on the definition of various types of innovation. According to the Oslo Manual, four types of innovation are distinguished: product, process, organisational, and marketing. Product innovations, which represent new or significantly improved products or services, can be said to differ in their main features from the previous products of the firm. Product innovations are further classified as innovations new to the market or new to the firm. Process innovation is defined as the implementation of a new or significantly improved production process, distribution method, or support activity for goods or services. Organisational innovation is defined as the introduction of (i) significantly changed organisational structures, (ii) advanced management techniques, or (iii) new or substantially changed corporate strategic orientations. Marketing innovation focuses on customer needs, engaging new markets, or newly positioning a firm's product on the market with the objective of increasing the firm's sales.

One strand of the literature has evolved assessing the impact of different innovation activities in favouring firm productivity. Nevertheless, the empirical evidence on this relationship varies among types of firms and measurements of productivity, as well as across different types of innovation. Empirical research has mainly focused on the innovation and firm level productivity nexus from the input side, measuring innovative inputs with traditional proxies such as R&D spending expenditure. Most studies on R&D expenditure find it to have a positive effect on productivity. In terms of outputs of innovation, patents are the most widely studied factor in the literature demonstrating that patents have a significant impact on firms' performance (for a survey of the literature, see Hall, Mairesse, and Mohnen 2010).

Only recently has the focus changed towards the output-orientated view, discriminating between different types of innovation. In terms of product innovation, Mohnen and Hall (2013) suggest that product innovation benefits firms' productivity by creating a new source of demand, potentially giving rise to scale effects or requiring less in terms of inputs than the old products. On the other hand, productivity may decline through the driving out of old products from the market, otherwise known as the cannibalising effect of new products. Further, when a new product is launched to the market, productivity might decrease initially; afterwards, it may improve, due to learning effects. Most studies have revealed a positive effect on productivity, whereas a limited number of studies have shown a negative effect (Mairesse and Robin 2009; Raffo, Lhuillery, and Miotti 2008).

Process innovation is a priori expected to have a more prominent positive effect on productivity, as such innovation is more about decreasing unit costs of production or delivery, increasing the quality hence is related to cost effectiveness and is inherently technological in nature (Mohnen and Hall 2013). Negative effects may arise due to the fact that innovations have possible disruptive effects on the firm in the short run, owing to inefficient production at the beginning stages of mass production (Roper, Du, and Love 2008). Although a typical firm may gain some market power via process innovation, if it is operating in the inelastic portion of its demand curve, its revenue productivity might fall when it becomes more cost efficient (Hall 2011). Indeed, while some studies reveal a positive effect of process innovation on productivity, some others reflect negative effects (Lööf and Heshmati 2006; Masso and Vahter 2008).

Effects of organisational innovations on firm performance increasing competitiveness have been proven by a limited number of studies, indicating two different sets of results (Armbruster et al. 2008; Piva and Vivarelli 2002). Organisational innovations aim to reduce administrative or transaction costs and improve workplace satisfaction and hence labour productivity, gain access to non-tradables, or reduce supply costs. Next, organisational innovations have an immediate positive effect on firm performance with regard to productivity, as they improve the quality and flexibility of firm operations (Goldman, Nagel, and Preiss 1995). On the other hand, marketing is well recognised to include strategic moves and these can be perceived as intangible assets affecting firm performance (Teece, Pisano, and Shuen 1997; Wernerfelt 1984). Through marketing innovations, implementation of new sales and distribution methodologies can lead to higher firm efficiency and performance.

To the best of our knowledge, there is no study examining the effect of innovation on productivity for Turkish firms using non-traditional proxies for innovation, except R&D, via the analysis of differential impacts of different types of innovations. Indeed, this nexus has not been handled within the context of the global crisis either. Existing micro level studies on Turkey dealing with firms' innovation activities mostly focus on the traditional input side proxies of innovation such as R&D spending. Only Ülkü and Pamukçu (2015) examine the effect of R&D on the productivity level of Turkish firms. Their findings show that an increase in R&D intensity enhances productivity only above a certain threshold level of technological capability for manufacturing firms. Another set of studies explores the relationship between such innovation proxies and other performance indicators of firms, apart from productivity (see among others Lo Turco and Maggioni 2015).

Another line of studies investigates the effect of the global financial crisis on the innovation activities of firms, where heterogeneous responses arise due to the recession (Archibugi, Filippetti, and Frenz 2013; Paunov 2012). However, little attention has been paid to how the complex relationship between innovation and firm performance differs when firms are exposed to economic crisis. Antonioli et al. (2013) analyse the role of innovation activities on the performances of Italian firms and suggest that the hypothesis of innovative firms' higher performance (in terms of labour productivity, employment, and profitability) might be broken during recession periods. Analysing the effects of various innovation indicators on the labour productivity of manufacturing enterprises Teplykh (2017) suggests that regardless of the innovation proxy applied (patents, awards, and R&D capital intensity), no significant effects on productivity can be found either in the pre-crisis or post-crisis periods.

3. Data

3.1. Description of the data-set

We utilise a recent and comprehensive firm level data-set for Turkish manufacturing firms over the period 2003–2012. For the analyses, three different sources of data collected by TURKSTAT are combined.[1] The first is the Community Innovation Surveys (CIS) that are based on the Oslo Manual guidelines cover information on innovative activities of firms, the sources of information, and the costs of these activities. The variables in CIS characterise the treatments within the framework of our empirical investigation and they correspond to three-year periods. CIS data cover the whole population of firms with more than 250 employees, whereas it presents a representative sample for firms with 10–250 employees. The second source of data is Structural Business Statistics (SBS), giving detailed information on firms' income, input costs, and employment and investment expenditures. Lastly, we use Annual Trade Statistics (ATS), which include information on export and import flows of firms. Combining CIS, SBS, and ATS, we focus on Turkish manufacturing firms where our data-set includes a representative sample for firms with 20–250 employees and the whole population of firms with more than 250 employees. We pooled four CIS waves corresponding to 2006, 2008, 2010, and 2012; thus, in total, we have 8532 observations of 6681 firms over 2003–2012.

3.2. Selection of variables

3.2.1. Innovation variables

Exploiting our rich data-set, we adopt an input-output approach in which we dissect the effects of innovative inputs as well as outputs of innovation. As innovation inputs, we distinguish between firms that have embodied and disembodied innovative inputs. With regard to innovation outputs, we distinguish between four types of firms, that is firms that

[1]These datasets are available under a confidential agreement and all the elaborations can only be conducted at the Microdata Research Centre of TURKSTAT in respect of the laws on the confidentiality of statistics and personal data protection.

undertake *product innovation*, firms that undertake *process innovation*, firms that undertake *organisational innovation*, and firms that undertake *marketing innovation*. We further distinguish between different types of product innovation, that is *product/service new to the firm* and *product/service new to the market.*

In Table 1, we provide detailed definitions and descriptive statistics for the innovation indicators. First, firms in our data-set seem to prefer to engage in internal generation of knowledge rather than searching for external sources. In fact, on average 42% of firms has embodied innovative inputs, whereas only 19% acquire disembodied inputs. Further, from the indicators of innovation outputs, we see that there does not exist much variation for firms in terms of producing different kinds of innovation outcomes.

3.2.2. Outcome variable

As we aim to investigate the effects of innovation on productivity of firms, our main variable of interest is total factor productivity (TFP), which is measured by Levinsohn and Petrin's (2003) semi-parametric approach at two-digit sectoral level. Levinsohn and Petrin (2003) assume the production technology to be of Cobb-Douglas form, in which the logarithm of firms' output is explained by the logarithm of labour, material inputs, and energy input and capital. Table A1 in Appendix 1 presents the descriptive statistics for the variables utilised in TFP estimations[2].

3.2.3. Control variables

In terms of control variables, we utilise capital intensity, number of employees, and dummies for intangible assets, subcontracting, outsourcing, export status, foreign ownership, region (identifying 12 Turkish regions distributed according to the NUTS2 classification), and four-digit sector dummies classified according to NACE Rev. 1.1 (see Table A2 in the Appendix 1 for the explanations and descriptive statistics of the outcome and control variables). In order to avoid potential endogeneity, we lag the above mentioned time-variant control variables by four years. Note that, since we pooled four CIS waves corresponding to 2006, 2008, 2010, and 2012, for each observation entering in any wave, we employ the controls at their $t - 4$ value. For instance, for the observations in 2006 wave, we utilise all the control variables at their values in 2003.

We utilise additional key control variables in our econometric specifications. First, we derive instruments for other types of innovation and public support instruments. The need for instruments for other types of innovations stems from the fact that an endogeneity issue may arise between different innovation indicators, due to the complementary relationship among different forms of innovation (Doran 2012). Thus, we need to control what else the firm is doing in other areas of innovation activities. For instance, firms that engage in product innovation might be more likely to introduce process innovations and vice versa. Firms investing in some kind of R&D are more likely to produce innovation outcomes, while the reverse is also possible. Therefore, by means of a multivariate probit model, we investigate whether our innovation variables are related or unrelated and estimate instruments for other innovation activities.

First of all, taking embodied and disembodied inputs of innovation as aggregate R&D investment, we introduce five variables capturing other innovation activities of firms; other

[2]Coefficients of labour and capital from the Levinsohn and Petrin (2003) estimations are available upon request.

Table 1. Definitions and descriptive statistics of innovation variables.

Variables	Definition	Percentage of firms	Number of firms
Embodied innovative inputs	=1 if firm has intramural R&D expenditures and/or invested in innovative machinery or equipment over the last 36 months, 0 otherwise	41.54	3805
Disembodied innovative inputs	=1 if firm has extramural R&D expenditures and/or acquired external knowledge from other enterprises or organisations such as patents, know-how, and other types of knowledge over the last 36 months, 0 otherwise	19.53	1789
Product/service innovation	=1 if firm 'developed successfully a major new product line or service over the last 36 months, and/or if the firm "upgraded an existing product line or service" over the last 36 months, 0 otherwise	36.27	3322
Process innovation	=1 if firm has 'acquired new production technology over the last 36 months, 0 otherwise	39.08	3579
Organisational innovation	=1 if firm has had 'a completely new organisational structure' or 'had a major reallocation of responsibility and resources between departments' over the last 36 months, 0 otherwise	40.85	3741
Marketing innovation	=1 if the firm had positive spending on R&D including wages and salaries of R&D personnel, R&D materials, R&D education and R&D related training over the last 36 months, 0 otherwise	40.75	3732
Product/service innovation new-to-firm	=1 if firm 'developed successfully a major new product line or service over the last 36 months which were new only for the firm, and/or if the firm "upgraded an existing product line or service" over the last 36 months which were new only for the firm, 0 otherwise	22.02	2017
Product/service innovation new-to-market	=1 if firm 'developed successfully a major new product line or service over the last 36 months which were new to both the firm and the market, and/or if the firm "upgraded an existing product line or service" over the last 36 months which were new to both the firm and the market, 0 otherwise	25.23	2311

innovation activity variable for R&D, other innovation activity variable for product/service innovation, other innovation activity variable for process innovation, other innovation activity variable for organisational innovation, and other innovation activity variable for marketing innovation. For example, the other innovation activity variable for product/service innovation takes value 1 if the firm is making R&D expenditures and/or engaging in a process innovation and/or engaging in organisational innovation and/or engaging in marketing innovation. Next, we run the multivariate probit model including five equations for observed 'other innovation activity' of firms and take the predicted values from these regressions as our other innovation activity instruments. Thus, we have five other innovation activity instruments, for firms that make R&D investment or not, engaged in product innovation or not, firms that engaged in process innovation or not, firms that have engaged in organisational innovation or not, and firms that have engaged in marketing innovation or not.[3] The multivariate probit specification takes the following form (Galia and Legros 2004):

$$E_{ij} = \delta_j + \beta_j Controls_{ij} + \eta_{ij} \tag{1}$$

$$i = 1, \ldots, n; j = 1, \ldots, 5; E\left[\eta_{i1}\right] = E\left[\eta_{i2}\right] = E\left[\eta_{i3}\right] = E\left[\eta_{i4}\right] = E\left[\eta_{i5}\right];$$

$$Var\left[\eta_{i1}\right] = Var\left[\eta_{i2}\right] = Var\left[\eta_{i3}\right] = Var\left[\eta_{i4}\right] = Var\left[\eta_{i5}\right] = 1; Cov\left[\eta_{ij}\right] = p \ \forall j.$$

In the above setting, the vector of controls $Controls_{ij}$ is restricted to firm size dummies (small, medium, and large firms[4]), four-digit sector dummies, and the export status dummy[5].

Later on, we estimate public support instruments employing a methodology similar to the one we use to derive other instruments to measure effort. Similar, an endogeneity issue may arise between public support and innovation decisions. Thus, by means of a multivariate probit model we estimate instruments for public support variables. We run the multivariate probit model including three equations for observed 'public support status' of firms and take the predicted values from these regressions as our other innovation activity instruments. Accordingly, we have three public support instruments for firms that receive subsidies from central government; subsidies from local/regional government agencies; and subsidies from the European Union, respectively. The multivariate probit specification is similar to Equation (1), now where the vector of $Controls_{ij}$ is composed of firm size dummies, export status dummy, a dummy variable indicating the technology level of the industry in which a firm is operating according the OECD's (2011) classification of manufacturing industries by technology intensity, and a group dummy taking value 1 if a firm is a member of group of firms composed of companies that are owned by the same legal or physical entity[6].

[3]Note that, we do not distinguish between product/service innovation new to the firm and product/service innovation new to the market and use the 'other innovation activity' instrument for product/service innovation for both types.
[4]Firms with number of employees 20–100; 101–249 and 250 + are defined as small, medium and large, respectively.
[5]See Table A3 in Appendix 1 for the marginal effects estimated from Equation (1).
[6]The marginal effects estimated from the regarding specification are available upon request.

4. Methodology

In order to conduct our analyses on the innovation-productivity relationship for Turkish firms, we utilise an endogenous switching technique, allowing us to exploit the richness of our data-set as well as to control for endogeneity and selection bias issues. By using endogenous switching methodology (ESM), we take into account the potential endogeneity between firms' productivity and innovation activity through estimating an auxiliary regression (Dutoit 2007).

Our methodology deals with the sample selection problem, which occurs when observations are non-randomly sorted into discrete groups (innovator firms vs. non-innovator firms), resulting in the potential for coefficient bias in estimation procedures such as ordinary least squares. In our case, the non-random sample of innovators could lead to selection bias if the determinants of being an innovator are correlated with the error term. ESM deals with this possible bias by modelling the specification in a two-stage framework (Lokshin and Sajaia 2004). Accordingly, in the first stage, we use a selection model for innovation decision, where I_i is a latent variable for the decision to innovate, both in terms of innovation inputs and outputs:

$$I_i = 1 \; if \; \alpha Z_i + \mu S^*_{ij} + \partial E^*_{ij} + \eta_i > 0 \tag{2}$$

$$I_i = 0 \; if \; \alpha Z_i + \mu S^*_{ij} + \partial E^*_{ij} + \eta_i \leq 0 \tag{3}$$

where η_i is the random disturbance term. Z_i is a vector including a set of firm-specific variables regarding the decision to innovate. These variables are capital intensity, logarithm of number of employees, export status, foreign ownership, region dummies, and four-digit sector dummies. S^*_{ij} and E^*_{ij} are other variables associated with innovation decisions, where S^*_{ij} represents the vector of public support instruments and E^*_{ij} is the instrument for other types of innovation activities as described in Section 3.2.2. In this step, firms face two regimes, (1) to innovate and (2) not to innovate, defined as follows:

$$\text{Regime 1:} \quad Y_{1i} = \beta_1 X_{1i} + \varepsilon_{1i} \; if \; I_i = 1 \tag{4a}$$

$$\text{Regime 2:} \quad Y_{2i} = \beta_2 X_{2i} + \varepsilon_{2i} \; if \; I_i = 0 \tag{4b}$$

where Y_{1i} is the TFP in logarithmic form for innovating firms in regime one and Y_{2i} is the TFP in logarithmic form for non-innovating firms in regime two. X_{1i} and X_{2i} are vectors of controls for regimes one and two. These are capital intensity, logarithm of number of employees, export status, foreign ownership dummy, region dummies, and four-digit sector dummies, as well as our other innovation effort instrument. ε_{1i} and ε_{2i} are the random disturbance terms. We run the endogenous switching model for the eight different treatments of innovation separately. Equations (1), (2), (4a), and (4b) are estimated with simultaneous maximum likelihood techniques, correcting for potential selection bias (Dutoit 2007; Lokshin and Sajaia 2004).

The ESM can be used to analyse firms' relative performance from engaging or not engaging in some kind of innovating activity. This analysis can be realised through comparing the conditional expectations derived from the endogenous switching regression model

Table 2. Conditional expectations and treatment effects.

	Decision stage		
Subsamples	To innovate	Not to innovate	Treatment effects
Firms that innovated	(a) $E(Y_{1i}\|I_i = 1)$	(c) $E(Y_{2i}\|I_i = 1)$	TT
Firms that did not innovate	(d) $E(Y_{1i}\|I_i = 0)$	(b) $E(Y_{2i}\|I_i = 0)$	TU

Notes: (a) and (b) represent the actual expectations observed in the sample; (c) and (d) represent counterfactual expected outcomes.
$I_i = 1$ if firms engaged in innovative activity; $I_i = 0$ if firms do not innovate;
Y_{1i} : productivity of firms if they innovated; Y_{2i} : productivity of the firms if they did not innovate;
TT: the effect of the treatment (i.e. innovation) on the treated (i.e. firms that innovated);
TU: the effect of the treatment (i.e. innovation) on the untreated (i.e. firms that did not innovate);

and these can be used to compare observed outcomes with counterfactual hypothetical cases. The conditional expectations for TFP are presented in Table 2 and defined as follows: $E(Y_{1i}|I_i = 1)$ (entry (a) in Table 2) represents the conditional expectation of innovating firms' productivity from innovating (observed); $E(Y_{2i}|I_i = 1)$ (entry (c) in Table 3) represents the conditional expectation of innovating firms' productivity if they did not innovate (counterfactual); $E(Y_{1i}|I_i = 0)$ (entry (d) in Table 2) represents the conditional expectation of non-innovating firms' productivity if they innovated (counterfactual); $E(Y_{2i}|I_i = 0)$ (entry (b) in Table 2) represents the conditional expectation of non-innovating firms' productivity from not innovating (observed).

Following Heckman, Tobias, and Vytlacil (2001), the effect of the treatment (i.e. innovation) on the treated (i.e. firms that innovated), 'TT', is calculated as the difference between (a) and (c). TT represents the innovating firms' mean productivity gain or loss from innovation. Likewise, the effect of the treatment (i.e. innovation) on the untreated (i.e. firms that did not innovate), 'TU', is calculated as the difference between (d) and (b). TU represents the non-innovating firms' mean productivity gain or loss from non-innovating. This step assesses whether the effect of engaging in innovation on productivity is higher for firms that actually innovated or for firms that did not innovate, than in the counterfactual case had they innovated. Calculating treatment effects enables us control for possible self-selection of more productive firms into innovation activity. To test the significance levels for differences in Equations (5a) and (5b), t-tests are applied[7].

$$\mathrm{TT} = E(Y_{1i}|I_i = 1) - E(Y_{2i}|I_i = 1) \tag{5a}$$

$$\mathrm{TU} = E(Y_{1i}|I_i = 0) - E(Y_{2i}|I_i = 0) \tag{5b}$$

5. Results

5.1. Innovation selection estimation

In the first step of our estimations, we investigate factors enhancing firms' likelihood of engaging in innovative activities. We find an endogenous relationship between productivity and all types of innovative activities, where we reject the null hypothesis of the likelihood ratio (LR) test of independent equations.[8] Table 3 presents the results of the endogenous switching regression estimated by full information maximum likelihood methodology

[7]The standard errors of all equations as well as of the treatment effects are bootstrapped.
[8]The likelihood ratio test shows that we can reject the null hypothesis (with p-value 0.000), indicating that the equations measuring each type of innovation indicator and productivity are independent.

Table 3 ESM innovation selection estimation

	Internal R&D	External R&D	Product/Service	Process	Organisational	Marketing	New to firm	New to MARKET
Other effort	2.068***	1.696***	0.668*	0.720**	0.0823	0.228	0.540**	0.666**
	(0.222)	(0.275)	(0.375)	(0.311)	(0.151)	(0.286)	(0.259)	0.278
Employee	0.104***	0.435***	0.170***	0.175***	0.101***	0.195***	0.183***	0.159***
	(0.027)	(0.033)	(0.028)	(0.031)	(0.027)	(0.024)	(0.022)	(0.026)
Capital intensity	0.274	0.368	0.426	0.342	0.098	0.076	0.901	0.714
	(0.270)	(0.546)	(0.534)	(0.505)	(0.225)	(0.518)	(0.638)	(0.546)
Foreign affiliation	0.167***	0.126*	0.039	0.098*	0.243***	0.125**	0.0266	0.0844
	(0.050)	(0.073)	(0.052)	(0.050)	(0.049)	(0.049)	(0.053)	(0.053)
Export status	0.134***	0.284***	0.166***	0.235***	0.200***	0.119***	0.131***	0.306***
	(0.0424)	(0.0554)	(0.044)	(0.0434)	(0.0394)	(0.0415)	(0.0452)	(0.0450)
Intangible assets	0.183***	0.0956*	0.137***	0.141***	0.162***	0.131***	0.0957***	0.138***
	(0.0315)	(0.054)	(0.0316)	(0.0313)	(0.0309)	(0.0298)	(0.0357)	(0.0352)
Subcontracting	0.123***	0.0899**	0.0560*	0.102***	0.115***	0.105***	0.0334**	0.0995***
	(0.033)	(0.046)	(0.0334)	(0.0330)	(0.0302)	(0.0325)	(0.0162)	(0.0358)
Outsourcing	0.194***	0.152***	0.138***	0.138***	0.091**	0.054***	0.276***	0.110**
	(0.042)	(0.048)	(0.042)	(0.041)	(0.039)	(0.011)	(0.045)	(0.044)
Subsidies from government	1.545***	1.160***	1.620***	1.233***	0.899***	1.116**	0.633***	0.864***
	(0.078)	(0.052)	(0.035)	(0.035)	(0.034)	(0.085)	(0.045)	(0.046)
Subsidies from region	1.150***	0.991***	1.392***	1.015***	0.892***	0.993***	1.001***	0.779***
	(0.094)	(0.053)	(0.033)	(0.073)	(0.049)	(0.070)	(0.060)	(0.060)
Subsidies from EU	0.154	0.149	0.317**	0.007	0.008	0.265	0.321**	0.0106
	(0.799)	(0.883)	(0.110)	(0.115)	(0.990)	(0.211)	(0.147)	(0.150)
Wald Chi2	46.90(0.000)	35.08(0.000)	49.42(0.000)	51.34(0.000)	57.63(0.000)	55.33(0.000)	30.98(0.000)	30.77(0.000)
Log likelihood	−1469.96	−1344.57	−1474.32	−1485.15	−1969.56	−1506.66	−1395.96	−1386.62
Observations	8351	8351	8351	8351	8351	8351	8351	8351

Notes: Reported are the estimated regression coefficients and the robust standard errors (in parentheses) from estimations. Asterisks denote significance levels (***$p < 1\%$; **$p < 5\%$; *$p < 10\%$). All regressions include region and sector dummies as controls.

for innovation indicators. The coefficient of the innovation effort indicator is found to be positive and significant for all innovative inputs. This suggests that, for example, internal R&D is dependent on other efforts, that is, various innovation outputs. As expected, the complementarity relationship is more pronounced for embodied innovation inputs than for disembodied innovation inputs. Among innovation outputs, product/service and process innovations are linked to other types of innovation efforts. This complementarity is more evident for product/service innovations than for process innovations. Among different types of product/service innovations, innovations new to the market that are more radical are supported by other types of innovations more than incremental innovations are.

Both indicators of internationalisation, namely foreign affiliation and export status, positively and significantly increase the likelihood of investing in innovative inputs. In fact, foreign affiliation increases the probability of innovative outputs, except for product innovation and its forms. This finding for product innovation might be due to the fact that foreign counterparts of multinational firms in host countries might hesitate to implement product innovation, as innovative products are associated with higher marginal costs. As standard in the literature, we confirm that firms that are larger, that invest in intangible assets, and that outsource and subcontract are more likely to engage in some kind of innovation activity. Note that subsidies from national resources have positive effects for all types of innovative activities, while the subsidies from EU sources are found to be significant only for product innovations (especially for incremental innovations). This may indicate inefficiencies in distribution or supervision of the EU subsidies for Turkey.

5.2. Estimation of treatment effects

Next, we explore the relationship between innovation and productivity for firms engaging and not engaging in innovative activities. As discussed earlier, we employ ESM to identify the correlation between firms' decision to innovate and TFP, specifically whether there is endogeneity between innovation and productivity. In fact, we do find an endogenous relationship between all innovation types and productivity.

5.2.1. Treatment effects for innovation inputs

Table 4 presents the expected TFP under actual conditions and counterfactual scenarios for innovative inputs, where Panel A shows the results for embodied inputs and Panel B provides the results for disembodied inputs. Cells (a) and (b) signify the expected TFP that can be observed from the sample. The expected TFP of firms that invested in internal R&D is about 8.101, whereas it is about 7.992 for the group of firms that did not invest. Cells (c) and (d) denote the expected TFP in the counterfactual scenarios. In case (c), firms that actually invested in embodied inputs would have TFP around 8.063 if they did not invest. In case (d), had firms that did not invest invested, their TFP level would be 8.145. Productivity levels can be compared for observed and counterfactual cases only within the same subsample (e.g. firms that invest). Thus, the last column of Table 4 presents the treatment effects of innovation on the treated (TT) on TFP, which is derived as the difference between cells (a) and (c). TT shows that innovating firms' mean productivity gain from innovation is 0.038 percentage points. That is, firms that actually invested in embodied inputs would be less productive if they did not invest. Further, the treatment effects of innovation on the untreated (TU) on TFP is calculated as the difference between cells (b) and (d). TU shows

Table 4. ESM treatment effects for innovative inputs.

	Decision stage		
Subsamples	To invest	Not to invest	Treatment effects
PANEL A: Internal R&D			
Firms that invested	(a) 8.101	(c) 8.063	TT= 0.038***
Firms that did not invest	(d) 8.145	(b) 7.992	TU= 0.153***
PANEL B: External R&D			
Firms that invested	(a) 7.907	(c) 7.874	TT= 0.033***
Firms that did not invest	(d) 7.994	(b) 7.869	TU= 0.125***

Note: Asterisks denote significance levels (***$p < 1\%$; **$p < 5\%$; *$p < 10\%$).

that non-innovating firms' mean productivity loss from not innovating is 0.153 percentage points. That is, firms that did not invest would be more productive had they invested. These results show not only that intramural R&D efforts of Turkish manufacturing firms yield productivity gains, but also that significant losses arise from not engaging in R&D activities. This result is consistent with the fundamentals of endogenous growth theories that define individual firms' R&D efforts as an unobserved and key component of output growth (Grossman and Helpman 1991). However, studies on the impact of intramural R&D on productivity provide mixed results for emerging economies (Arza and López 2010). With regard to Turkey, Ülkü and Pamukçu (2015) find significant productivity effects of in-house R&D for Turkish manufacturing firms with a certain level of technological capability.

Table 4 further presents the expected TFP under actual conditions and counterfactual scenarios for disembodied innovative inputs in panel B. Similar to the results from embodied innovative inputs, firms that actually invested in disembodied inputs would be less productive if they did not invest. Moreover, firms that did not invest in disembodied inputs would be more productive had they innovated. These results imply a positive effect on the productivity levels of firms investing in disembodied innovative inputs. Disembodied innovative inputs involve purchasing, transferring, or licensing knowledge from other enterprises and organisations. Regardless of the source of the knowledge accumulation efforts, once individual firms acquire and internalise outsourced R&D consistent with an endogenous growth framework, these efforts might yield productivity gains. Further, external R&D brings productivity improvements due to economies of specialisation and/or knowledge spillovers.

The treatment effects on productivity for internal R&D are higher than those of outsourced R&D, suggesting a more central role for internally developed research. Outsourced R&D may not boost productivity as much as internal R&D, due to the issues related to the absorptive capacity of firms in internalising external knowledge, coordination failures with the external providers of R&D, or problems related with acquiring know-how. Cohen and Levinthal's (1989) famous approach of absorptive capacity is empirically supported by several studies confirming that technological capability is crucial for successful use of external technology (Lall 1992). Further, embodied R&D investments specifically in the form of the acquisition of new machinery have direct effects on productivity or capacity utilisation. This result also emphasises that inherently firm-specific knowledge is more valuable.

5.2.2. Treatment effects for innovation outputs

Table 5 gives the expected TFP under actual conditions and counterfactual scenarios for innovative outputs. Panel A presents the respective results for product/service innovation.

Table 5. ESM treatment effects for innovation outputs.

	Decision stage		
Subsamples	To innovate	Not to innovate	Treatment effects
PANEL A: Product/Service innovation			
Firms that made innovation	(a) 8.127	(c) 8.072	TT= 0.055
Firms that did not make	(d) 8.193	(b) 8.016	TU= 0.177***
PANEL B: Process innovation			
Firms that made innovation	(a) 7.902	(c) 7.809	TT= 0.093***
Firms that did not make	(d) 7.997	(b) 7.815	TU= 0.182***
PANEL C: Organisational Innovation			
Firms that made innovation	(a) 8.052	(c) 7.981	TT= 0.071***
Firms that did not make	(d) 8.067	(b) 7.904	TU= 0.163***
PANEL D: Marketing Innovation			
Firms that made innovation	(a) 7.752	(c) 7.701	TT= 0.051
Firms that did not make	(d) 8.108	(b) 7.968	TU= 0.140***

Note: Asterisks denote significance levels (***$p < 1\%$; **$p < 5\%$; *$p < 10\%$).

The treatment effect is found to be insignificant, indicating that product/service innovation does not have an effect on productivity levels of innovating firms. On the other hand, firms that did not innovate would be more more productive had they innovated. These results indicate that while innovating firms do not gain from product/service innovation, non-innovating firms incur productivity losses from not innovating. Introducing a new or an upgraded line or service might have opposing effects on productivity through expanding demand (direct demand effect) and creating economies of scale, as well as exercising a cannibalising effect (indirect demand effect) on the old products (Mohnen and Hall 2013). Such insignificant effects of product/service innovation on the productivity of innovating firms might stem from these two effects cancelling out each other.

Panel B shows the respective results for process innovation. Treatment effects indicate a strong association between process innovation and productivity, such that not only innovating firms enjoy higher productivity, but also significant losses arise from not innovating. Process innovation is a priori expected to have a more prominent positive effect on productivity, as it is directly related to reductions in costs. This input-saving effect of process innovation might yield price reductions and further productivity improvements along the elastic portion of the demand curve (Mohnen and Hall 2013). There is mixed evidence in the literature with regard to the impact of process innovation on productivity of firms. While some studies point to a positive effect of process innovation in developing (Chudnovsky, López, and Pupato 2006; Masso and Vahter 2008) and developed (Parisi, Schiantarelli, and Sembenelli 2006) economies, others reveal negative or insignificant effects (Lööf and Heshmati 2006).

In Panels C and D, we see the results for organisational and marketing innovation respectively. We observe positive and significant treatment effects for organisational innovations. As organisational innovations improve the quality and flexibility of firm operations, productivity improvements are expected. Good management practices are well established in the marketing literature as being important for firm productivity. Accordingly, firms with better management practices tend to be more productive. Yet, empirical evidence on the role of organisational innovation on productivity is limited and mixed. Some studies indicate a positive effect whereas others reveal negative or insignificant effects (Lööf and Heshmati 2006; Musolesi and Huiban 2010; Raffo, Lhuillery, and Miotti 2008).

Among non-technological innovations, marketing innovation, which involves the implementation of new marketing practices, include changes in sales, distribution methods, product design and packaging, and methods for pricing goods and services. Thus, in terms of marketing innovation, there might be room for productivity improvements through increased sales. We find weaker support for the effect of marketing innovation on productivity. The results in Panel D indicate that while innovating firms do not benefit from marketing innovation, non-innovating firms incur marginal losses in terms of productivity from not innovating. Among all the typologies of innovation, marketing innovation is the least explored. Within this limited number of studies, Greenan and Guellec (1998) and Black and Lynch (2004) find a positive effect for French and US firms respectively.

Our findings reveal a clear ranking of productivity gains from different typologies of innovation outputs. The hierarchy of treatment effects starts with process innovation, followed by organisational, then product/service, then marketing innovation. We observe the highest productivity gains with process innovation. This result is not surprising, as process innovations are a priori expected to have stronger effects than other types of innovations, since they are technological innovations introduced primarily with the aim of reducing production costs and improving efficiency. As regards product/service innovation, while innovating firms do not gain from product/service innovation, non-innovating firms' mean productivity losses from non-innovating is smaller than it is with respect to process innovation. This comparatively weak result for product/service innovation with respect to other innovation outputs (except marketing) is consistent with the theoretical view outlining time delays in transforming innovations into productivity improvements, owing to learning effects. Among non-technological innovations, which are incremental in nature, organisational innovation has a more pronounced effect with respect to marketing, as the effects of this typology of innovation are more akin to those of process innovation. Indeed, organisational innovations are by definition inclined to reduce administrative, transaction, and supply costs, aiming to increase productivity; whereas marketing innovations focus on customer needs, aiming to increase a firm's sales, which would have indirect effects on productivity. Our results are compatible with some other studies investigating the effect of various innovation forms on productivity. Most such studies comparing product and process innovations find process innovations to be more effective than product innovations for productivity gains (Chudnovsky, López, and Pupato 2006; and Parisi, Schiantarelli, and Sembenelli 2006). There are comparatively fewer studies that integrate non-technological innovations into the analysis. Among them, our hierarchy—running from process, then to organisational, and then to product innovation—is in line with the findings of Masso and Vahter's (2006) study of Estonia. In their study of Irish manufacturing firms, Crowley and McCann (2015) use ESM in similar manner to our study and find process innovations to be the most effective type of innovation, while product and organisational innovations are found to have negative effects on productivity. Finally, innovative outputs turn out to be a more direct driver of productivity than innovative inputs, as innovative inputs may take time to affect productivity, or they may simply not transform into innovative outputs and hence exert no direct impact on the productivity of firms.

In Table 6, we demonstrate the results for product/service new to the firm (Panel A) and the results for product/service new to the market (Panel B). First of all, in Panel A, we notice that firms that made product/service innovations new to the firm would be 0.071 percentage points less productive if they did not innovate and non-innovating firms' mean productivity

Table 6. ESM treatment effects for different types of product/service innovation.

	Decision stage		
Subsamples	To innovate	Not to innovate	Treatment effects
PANEL A: New to the Firm			
Firms that made innovation	(a) 8.063	(c) 7.992	TT= 0.071***
Firms that did not make	(d) 8.127	(b) 7.944	TU= 0.183***
PANEL B: New to the market			
Firms that made innovation	(a) 8.082	(c) 8.047	TT= 0.035
Firms that did not make	(d) 8.096	(b) 7.964	TU= 0.132*

Note: Asterisks denote significance levels (***$p < 1\%$; **$p < 5\%$; *$p < 10\%$).

loss is 0.183 percentage points. As product/service lines new to the firm can be considered as complementary to the existing products of the firm, they may bring about productivity gains through scale effects (Mohnen and Hall 2013). As shown in Panel B, the treatment effects are insignificant for firms that actually innovated. Moreover, non-innovating firms' mean productivity loss is smaller for product/service innovations new to the market than for product/service innovations new to the firm. As a product new to the market represents a more drastic innovation, it has a larger potential for improving productivity through expanding demand. However, its success is largely associated with the marketing of this new product. Further, the productivity effect stemming from this new product may be subject to certain time delays due to learning effects (e.g. workers' training). As a result, it might be more difficult or time-consuming for the firm to internalise and translate product/service innovations new to the market into productivity improvements.

5.2.3. Treatment effects over the business cycle

In this subsection, we present some further direct evidence on productivity effects of innovation over the business cycle. To investigate whether the innovation-productivity relation continues to hold over the economic cycle, we re-estimate our equations, dividing our sample into two subsamples for the pre-crisis period (2004–2008) and the post-crisis period (2010–2012). For the pre-crisis sub-period we utilise the 2006 and 2008 waves of CIS data and we use the 2012 wave for the post-crisis period. For Turkey, while a friendly environment in terms of both demand and external financing conditions characterises the pre-crisis period for firms[9], the post-crisis period is relatively tough. Even if the economy showed a very low growth performance of 2.2% in 2012, this period can be considered as a recovery/upturn phase after the crisis[10].

In Table 7, the treatment effects with respect to various innovation indicators from the two subsamples in question are presented. With regard to inputs of innovation, we observe that the role of both intramural and extramural R&D is positive and significant in both periods, but weakens following the crisis. This result suggests that in the post-crisis period, R&D investors have a lower capacity to translate investment in R&D into productivity gains. Similar results are obtained in Castellani et al. (2016), where EU and US companies' productivity gains from investments in R&D shrank in the post-crisis period with respect to the pre-crisis period. In light of this result, these researchers also conjecture that EU and

[9]The growth process of the Turkish economy accelerated remarkably during 2002–2007. While real GDP grew on average by 6.8% annually, manufacturing industry experienced a higher growth rate, on average 8.5%.
[10]In 2009, the economy shrunk by 4.7%.

Table 7. Treatment effects over the business cycle.

	Pre-Crisis ($N = 3990$)		Post-Crisis ($N = 3159$)	
	TT	TU	TT	TU
Internal R&D Innovation	0.041***	0.167***	0.033***	0.139***
External R&D Innovation	0.039***	0.134***	0.028***	0.111***
Product/Service Innovation	0.068	0.181***	0.051	0.162
Process Innovation	0.089***	0.175***	0.111***	0.188***
Organisational Innovation	0.082***	0.166***	0.053***	0.151***
Marketing Innovation	0.048	0.148***	0.055	0.112

Note: Asterisks denote significance levels (***$p < 1\%$; **$p < 5\%$; *$p < 10\%$).

US companies are affected by the economic crisis of 2008 in their capacity to translate R&D investments into productivity gains.

In terms of product innovations, the net effect on productivity is ambiguous, since it largely depends upon the relative size of the direct demand effect and the indirect demand effect (cannibalisation effect). However, which of these two effects is dominant may also depend on the macroeconomic conditions, in the sense that the decline in the old product's sales is expected to be larger in recessions than in boom periods (Peters et al. 2014). Table 7 shows that the already weak effect of product innovation on productivity disappears after the crisis. Although the Turkish economy is in a recovery period in terms of domestic and external demand after the crisis, expanding demand may not be sufficient to overcome the strong reduction of demand for the firms' old products. Put differently, the sales growth due to new products may not compensate for the loss of demand due to old products; hence the cannibalisation effect is likely to dominate the direct demand effect. Moreover, if we go back to Schumpeter's (1911) notion of extra-normal, monopolistic profits, which are considered as the main incentive for innovating, such profits can naturally be expected to be highest in favourable economic conditions, since strong demand growth limits competitive pressure. This positive association between product innovation and the business cycle is also confirmed by Judd (1985) who claim that markets have a limited capacity for absorbing new products in low demand conditions and thus firms are more likely to introduce new products under prosperous market conditions.

As for process innovations, the results in Table 7 highlight that there is a positive and significant association between firms' process innovation activity and their productivity levels over all stages of the business cycle. Further, process innovators have more of an advantage in terms of productivity from innovating in the post-crisis period. This finding also holds for non-innovators, in that they would incur more losses in terms of productivity from non-innovating in the pre-crisis period. This weakening effect in the pre-crisis period might be attributable to labour-saving behaviour on the part of firms in order to cut costs in the post-crisis period. While under favourable market conditions, firms may not find it compulsory to use the potential of new processes with the aim of reducing costs, under tougher market conditions, firms are more inclined to reduce average production costs via employing less labour input.

With regard to non-technological innovations, the results in Table 7 stress that while the positive relationship between firms' organisational innovation activity and their productivity level weakens after the crisis, for marketing innovations the relationship between innovation and productivity disappears after the crisis. This finding can be attributed to lower returns of innovation activities under non-favourable market conditions.

6. Concluding remarks

The overall picture from the analysis confirms firms' heterogeneity in terms of both their propensity to innovate and their benefiting from innovation activities. Our findings reinforce the view that there exists a complementary relationship between different forms of innovation. Specifically, engaging in one type of innovative activity triggers other forms such that a good balance among innovation activities could contribute more to firm productivity.

Among the control variables, public supports are found to have positive effects for all types of innovative activities, pointing out a clear avenue for policy intervention in terms of subsidies. Subsidies from national sources are found to be more effective than those from EU sources. The reason behind this finding might be the obstacles arising in the distribution or supervision of the EU subsidies. Thus, further research might be beneficial to inspect the success of national subsidy programs and the inefficiencies of EU funding. In the light of such research, existing channels could be empowered and new policy instruments could be designed.

Results reveal that innovative outputs turn out to be a more direct driver of productivity improvements than are innovative inputs, as innovative inputs may be exposed to time delays in affecting productivity, or they may simply not transform into innovative outputs and hence exert no direct impact on the productivity of firms. On the input side, we confirm the importance of R&D in spurring productivity, while internal R&D has a stronger association with productivity improvements than outsourced R&D. Since they have more direct effects on productivity or capacity utilisation, embodied R&D investments inherently build up firm-specific knowledge. On the other hand, outsourced R&D may incur problems related to the absorptive capacity of firms to internalise external knowledge or to coordination failures. Accordingly, as internally developed R&D is found to be more valuable for firms, for policy interventions, resources should be allocated to subsidise and support internal R&D investments of firms, instead of promoting external R&D.

On the output side, there is significant heterogeneity found in contributions to productivity coming from different typologies. Indeed, there exists a hierarchical structure of productivity gains, running from process to organisational to product/service to marketing innovation. We find a lack of effect of product/service innovation on productivity with respect to process or organisational innovations. This can be interpreted as a signal of time delays in terms of translating innovations into productivity gains, due to learning effects. Higher productivity gains arising from process and organisational innovations stem from the fact that these innovations are introduced with the aim of reducing costs. Another piece of evidence we provide is that incremental innovations are found to be more pronounced in fostering productivity gains than are radical innovations, as radical innovations might be more difficult for the firm to internalise and translate into productivity improvements.

Note that our counterfactual scenarios add further insights to the innovation-productivity nexus. Throughout the analysis, we show not only that firms that actually innovated would be less productive if they did not innovate, but also firms that did not innovate would be more productive had they innovated. The second finding is puzzling in the sense that engaging in innovation would improve non-innovating firms' productivity, but some firms are reluctant to do so. A reasonable explanation of their non-innovating behaviour could reveal the uncertain nature of innovation activity and firm heterogeneity in terms of barriers to innovate. Such heterogeneity in firm behaviour indicates heterogeneity in market failures, emphasising the importance of detailed firm-oriented policy design, instead of aggregate interventions at sectoral or country level.

Gathering direct evidence on productivity effects of innovation over the business cycle, we find that productivity gains from investments in R&D shrank in the post-crisis period by comparison with the pre-crisis period. This suggests that in the post-crisis period, R&D investors have a lower capacity to translate investment in R&D into productivity gains. Thus, although most policy attention has been devoted to the low levels of R&D spending in Turkey, policies should be directed to increase the firms' capabilities to turn R&D into productivity gains. With regard to product innovation, while the Turkish economy is in a recovery period in terms of domestic and external demand after the crisis, expanding demand seems insufficient to provide productivity gains from innovation. Process innovators are found to have more of an advantage from innovating in the post-crisis period, which might be attributable to the labour-saving behaviour of firms in order to cut costs in the post-crisis period.

Our micro-level evidence on the linkages between firms' innovation behaviour and their productivity gains in various phases of the economy provides motivation to research further the structural and policy challenges underlying the low innovation performance in Turkey. For both short and long term, it is crucial for such research on innovation performance and gains from such innovation to be placed at the centre of the development and growth policies.

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References

Antonioli, D., A. Bianchi, M. Mazzanti, S. Montresor, and P. Pini. 2013. "Innovation Strategies and Economic Crisis: Evidence from Italian Firm-Level Data." *Economia Politica* 30 (1): 33–68.

Archibugi, D., A. Filippetti, and M. Frenz. 2013. "Economic Crisis and Innovation: Is Destruction Prevailing over Accumulation?" *Research Policy* 42 (2): 303–314.

Armbruster, H., A. Bikfalvi, S. Kinkel, and G. Lay. 2008. "Organizational Innovation: The Challenge of Measuring Non-Technical Innovation in Large-Scale Surveys." *Technovation* 28 (10): 644–657.

Arza, V., A. López. 2010. Innovation and Productivity in the Argentine Manufacturing Sector. IDB Working paper series, No. IDB-WP-187.

Black, S. E., and L. M. Lynch. 2004. "What's Driving the New Economy?: The Benefits of Workplace Innovation." *The Economic Journal* 114 (493): 97–116.

Castellani, D., M. Piva, T. Schubert, and M. Vivarelli. 2016. "R&D and Productivity in the US and the EU: Sectoral Specificities and Differences in the Crisis." *Papers in Innovation Studies*, 15.

Chudnovsky, D., A. López, and G. Pupato. 2006. "Innovation and Productivity in Developing Countries: A Study of Argentine Manufacturing Firms' Behavior (1992–2001)." *Research Policy* 35: 266–288.

Cohen, W. M., and D. A. Levinthal. 1989. "Innovation and Learning: The Two Faces of R & D." *The Economic Journal* 99 (397): 569–596.
Crowley, F., and P. McCann. 2015. "Innovation and Productivity in Irish Firms." *Spatial Economic Analysis* 10 (2): 181–204.
Doran, J. 2012. "Are Differing Forms of Innovation Complements or Substitutes?" *European Journal of Innovation Management* 15: 351–371.
Dutoit, L. C. 2007. "Heckman's Selection Model, Endogenous and Exogenous Switching Models, a Survey." The Selected Works of Laure C Dutoit. http://works.bepress.com/laure_dutoit/3.
Galia, F., and D. Legros. 2004. "Complementarities between Obstacles to Innovation: Evidence from France." *Research Policy* 33: 1185–1199.
Goldman, S., R. Nagel, and K. Preiss. 1995. *Agile Competitors and Virtual Organisations: Strategies for Enriching the Customer*. New York: Van Nostrand Reinhold.
Grossman, G. M., and E. Helpman. 1991. "Trade, Knowledge Spillovers, and Growth." *European Economic Review* 35 (2–3): 517–526.
Greenan, N., and D. Guellec. 1998. "Firm Organization, Technology and Performance: An Empirical Study." *Economics of Innovation and New Technology* 6 (4): 313–347.
Hall, B. H. 2011. *Innovation and Productivity (No. W17178)*. National bureau of economic research.
Hall, B. H., J. Mairesse, and P. Mohnen. 2010. "Measuring the Returns to R&D." *Handbook of the Economics of Innovation* 2: 1033–1082.
Heckman, J. J., J. L. Tobias, and E. J. Vytlacil. 2001. "Four Parameters of Interest in the Evaluation of Social Programs." *Southern Economic Journal* 68 (2): 210–233.
Hud, M., and K. Hussinger. 2015. "The Impact of R&D Subsidies during the Crisis." *Research Policy* 44 (10): 1844–1855.
Judd, K. L. 1985. "On the Performance of Patents." Econometrica: Journal of the Econometric Society 567–585.
Lall, S. 1992. "Technological Capabilities and Industrialization." *World Development* 20 (2): 165–186.
Levinsohn, J., and A. Petrin. 2003. "Estimating Production Functions Using Inputs to Control for Unobservables." *The Review of Economic Studies* 70 (2): 317–341.
Lo Turco, A., and D. Maggioni. 2015. "Dissecting the Impact of Innovation on Exporting in Turkey." *Economics of Innovation and New Technology* 24 (4): 309–338.
Lokshin, M., and Z. Sajaia. 2004. "Maximum Likelihood Estimation of Endogenous Switching Regression Models." *Stata Journal* 4: 282–289.
Lööf, H., and A. Heshmati. 2006. "On the Relationship between Innovation and Performance: A Sensitivity Analysis." *Economics of Innovation and New Technology* 15 (4–5): 317–344.
Mairesse, J., and S. Robin. 2009. *Innovation and Productivity: A Firm-Level Analysis for French Manufacturing and Services Using CIS3 and CIS4 Data (1998–2000 and 2002–2004)* (Working Paper). Paris: CREST-ENSAE.
Masso, J., and P. Vahter. 2008. "Technological Innovation and Productivity in Late-Transition Estonia: Econometric Evidence from Innovation Surveys." *The European Journal of Development Research* 20: 240–261.
Mohnen, P., and B. H. Hall. 2013. "Innovation and Productivity: An Update." *Eurasian Business Review* 3 (1): 47–65.
Musolesi, A., and J. P. Huiban. 2010. "Innovation and Productivity in Knowledge Intensive Business Services." *Journal of Productivity Analysis* 34 (1): 63–81.
OECD (Organization for Economic Cooperation and Development). 1992, 1996, 2005. *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data Paris*.
Parisi, M. L., F. Schiantarelli, and A. Sembenelli. 2006. "Productivity, Innovation and R&D: Micro Evidence for Italy." *European Economic Review* 50 (8): 2037–2061.
Paunov, C. 2012. "The Global Crisis and Firms' Investments in Innovation." *Research Policy* 41 (1): 24–35.
Peters, B., B. Dachs, M. Dünser, M. Hud, C. Köhler, and C. Rammer. 2014. *Firm Growth, Innovation and the Business Cycle: Background Report for the 2014 Competitiveness Report*. ZEW Gutachten/ Forschungsberichte.

Piva, M., and M. Vivarelli. 2002. "The Skill Bias: Comparative Evidence and an Econometric Test." *International Review of Applied Economics* 16 (3): 347–357.
Raffo, J., S. Lhuillery, and L. Miotti. 2008. "Northern and Southern Innovativity: A Comparison across European and Latin American Countries." *The European Journal of Development Research* 20: 219–239.
Roper, S., J. Du, and J. H. Love. 2008. "Modelling the Innovation Value Chain." *Research Policy* 37: 961–977.
Schumpeter, J. A. 1911. *The Theory of Economic Development*. Cambridge: Harvard University Press.
Solow, R. M. 1957. "Technical Change and the Aggregate Production Function." *The Review of Economics and Statistics* 312–320.
Teece, D. J., G. Pisano, and A. Shuen. 1997. "Dynamic Capabilities and Strategic Management." *Strategic Management Journal* 509–533.
Teplykh, G. V. 2017. "Innovations and Productivity: The Shift during the 2008 Crisis." *Industry and Innovation* 1–31.
Ülkü, H., and M. T. Pamukçu. 2015. "The Impact of R&D and Knowledge Diffusion on the Productivity of Manufacturing Firms in Turkey." *Journal of Productivity Analysis* 44 (1): 79–95.
Wernerfelt, B. 1984. "A Resource-Based View of the Firm." *Strategic Management Journal* 5 (2): 171–180.

Appendix 1

Table A1. Descriptive statistics of the variables in TFP estimation.

	Number of observations	Mean
TFP (in logarithms)	8354	7.92
Value Added (Real, in millions)	8781	23.96
Capital Stock (In millions)	8768	58.61
Employee	9159	354.47
Material Inputs (Real, in millions)	8942	46.48
Electricity Expenditure (Real, in millions)	8864	0.53
Fuel Expenditure (Real, in millions)	9140	0.78
Energy (Real, in millions)	8864	1.32

Table A2. Descriptive statistics of the control variables.

Variables	Definition	Mean ($N = 9159$)	Pre-Crisis Mean ($N = 3990$)	Post-Crisis Mean ($N = 3159$)
TFP	Logarithm of Total Factor Productivity	7.92	7.97	7.88
Other Effort				
Other Effort for R&D	Instrument for other innovation activities than R&D	0.221	0.222	0.219
Other Effort for Product/Service Innovation	Instrument for other innovation activities than Product/Service Innovation	0.281	0.282	0.280
Other Effort for Process Innovation	Instrument for other innovation activities than Process Innovation	0.252	0.254	0.250
Other Effort for Organisational Innovation	Instrument for other innovation activities than Organisational Innovation	0.231	0.233	0.229
Other Effort for Marketing Innovation	Instrument for other innovation activities than Marketing Innovation	0.232	0.233	0.232
Employee	Number of employees	354.47	365.00	327.23
Capital Intensity	The ratio of the capital stock to the number of employees	154932.3	161914.2	151262.5
Foreign Affiliation	Dummy variable that takes value 1 if a firm's share of foreign capital is larger than zero	0.10	0.11	0.10
Export Status	Dummy variable that takes value 1 if firm exports	0.67	0.70	0.65
Outsourcing	Dummy variable that takes value 1 if the firm utilised a subcontractor firm for production	0.13	0.18	0.09
Subcontracting	Dummy variable that takes value 1 if the firm served as subcontractor firm for production	0.39	0.41	0.37
Intangible Assets	Dummy variable that takes value 1 if the firm invested in intangible assets	0.47	0.48	0.45
Public Support				
Subsidies from Government	Instrument for subsidies from central government	0.12	0.12	0.11
Subsidies from Region	Instrument for subsidies from local/regional government agencies	0.06	0.06	0.06
Subsidies from EU	Instrument for subsidies from the EU	0.01	0.01	0.01

Table A3. Marginal effects from estimation of other innovation activity instruments.

	Other effort				
	R&D	Product/Service	Process	Organisational	Marketing
Export Status	0.0348***	0.066**	0.126***	0.185***	0.122***
	(0.003)	(0.031)	(0.031)	(0.033)	(0.033)
Medium Size Firm	0.065*	0.071**	0.070**	0.086**	0.229***
	(0.037)	(0.035)	(0.035)	(0.037)	(0.037)
Large Size Firm	0.192***	0.130***	0.109***	0.047	0.224***
	(0.038)	(0.036)	(0.036)	(0.038)	(0.038)

Notes: Reported are the estimated regression coefficients and the robust standard errors (in parentheses) from estimations. Asterisks denote significance levels (***$p < 1\%$; **$p < 5\%$; *$p < 10\%$). All regressions include sector dummies as controls.