ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

R&D EXPENDITURES AND PRODUCTIVITY UNDER FINANCIAL CONDITIONS: STATIC AND DYNAMIC PANEL DATA ANALYSIS FOR FIRMS IN TURKIYE

M.A. THESIS

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

FİNANSAL KOŞULLAR ALTINDA AR-GE GİDERLERİ VE VERİMLİLİK: TÜRKİYE'DEKİ FİRMALARA YÖNELİK STATİK VE DİNAMİK PANEL VERİ ANALİZİ

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OCAK 2026

Büşra Kaya, an M.A. student of ITU Graduate School student ID 412221010, successfully defended the thesis/dissertation entitled “R&D EXPENDITURES AND PRODUCTIVITY UNDER FINANCIAL CONDITIONS: STATIC AND DYNAMIC PANEL DATA ANALYSIS FOR FIRMS IN TURKIYE”, which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission : 30 December 2025
Date of Defense : 30 January 2026

To my family,

FOREWORD

This thesis has been prepared within the framework of the Master's Program in Economics at Istanbul Technical University.

I would like to express my sincere gratitude to my advisor, Assoc. Prof. Dr. Osman Doğan, for his invaluable guidance throughout every stage of this thesis. His academic expertise, insightful feedback, patience, and continuous encouragement made this research process both possible and meaningful. I am deeply grateful for his support, which has been a constant source of motivation.

I would also like to thank the Central Bank of the Republic of Türkiye (CBRT) for providing me with the opportunity to pursue this master's degree. The analyses presented in this thesis have been conducted using unique data sources made available through the CBRT, and I sincerely appreciate the institutional support that contributed to this study.

I am infinitely grateful to my parents, Nurcan and Mehmet, my siblings, Mehmet Erdem and Melek, as well as my grandmother Durdane and my uncle Osman. Their unwavering support, patience, trust, and unconditional love have been my greatest source of strength, not only during the completion of this thesis but also throughout my life. I would also like to thank my dear friend, Tunahan, who motivated me and supported me along the way.

January 2026 Büşra KAYA

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ABBREVIATIONS

CBRT	**:** Central Bank of the Republic of Türkiye
R&D	**:** Research and Development
TFP	**:** Total Factor Productivity
LP	**:** Levinsohn and Petrin
ACF	**:** Ackerberg–Caves–Frazer
OP	**:** Olley and Pakes
GMM	**:** Generalized Method of Moments
IV	**:** Instrumental Variable
DEA	**:** Data Envelopment Analysis
UK	**:** United Kingdom
TE	**:** Technical Efficiency
OECD	**:** Organization for Economic Cooperation and Development
GDP	**:** Gross Domestic Product
TURKSTAT	**:** Turkish Statistical Institute
OLS	**:** Ordinary Least Squares
LP-ACF	**:** Levinsohn and Petrin with Ackerberg–Caves–Frazer correction
OP-ACF	**:** Olley and Pakes with Ackerberg–Caves–Frazer correction
PPI	**:** Producer Price Index

SYMBOLS

$\boldsymbol{Y_i}$	**:** Output for the firm i
$\boldsymbol{A}$	**:** Technology component
$\boldsymbol{K_i^\alpha}$	**:** Capital for the firm i with a weight component of α
$\boldsymbol{L_i^B}$	**:** Labor for the firm i with a weight component of B
$\boldsymbol{y_{it}}$	**:** Natural logarithm of the output for the firm i at time t
$\boldsymbol{k_{it}}$	**: N**atural logarithm of the capital for the firm i at time t
$\boldsymbol{l_{it}}$	**: N**atural logarithm of the labor for the firm i at time t
$\boldsymbol{\mu_{it}}$	**:** Observed shocks for the firm i at time t
$\boldsymbol{\nu_{it}}$	**:** Unobserved shocks for the firm i at time t
i	**:** Firm
j	**:** Sector
t	**:** Time
$\boldsymbol{TFP_{ijt}}$	**:** Total factor productivity for the firm i at sector j at time t
$\boldsymbol{B_0}$	**:** Intercept
$\boldsymbol{RD_{ijt}}$	**:** R&D expenditures for the firm i at sector j at time t
$\boldsymbol{X_{ijt}}$	**:** Control variables for the firm i at sector j at time t
$\boldsymbol{\varepsilon_{ijt}}$	**:** Error term for the firm i at sector j at time t
$\boldsymbol{RD_{ijt-1}}$	**:** R&D expenditures for the firm i at sector j at time t-1
$\boldsymbol{X_{ijt-1}}$	**:** Control variables for the firm i at sector j at time t
$\boldsymbol{\gamma_i}$	**:** Firm fixed effects
$\boldsymbol{\delta_j}$	**:** Sector fixed effects
$\boldsymbol{\lambda_t}$	**:** Time fixed effects
$\boldsymbol{Export_{ijt}}$	**:** Firms with an export ratio is higher than 50 percent for the firm i at sector j at time t
$\boldsymbol{TFP_{ijt-1}}$	**:** Total factor productivity for the firm i at sector j at time t
$\mathbf{B'}$	**:** Coefficient vector

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R&D EXPENDITURES AND PRODUCTIVITY UNDER FINANCIAL CONDITIONS: STATIC AND DYNAMIC PANEL DATA ANALYSIS FOR FIRMS IN TURKIYE

SUMMARY

This study examines the impact of research and development (R&D) expenditures on firms' total factor productivity (TFP) by explicitly accounting for firms' financial conditions. The analysis is based on a comprehensive firm-level dataset for Türkiye covering the period from 2009 to 2023. Balance sheet and income statement data reported to the Revenue Administration are combined with the Annual Industry and Service Statistics provided by the Turkish Statistical Institute, resulting in a unique panel dataset at the firm and industry levels. The empirical framework employs high-dimensional static and dynamic panel data models that control for firm, year, and industry fixed effects in order to address unobserved heterogeneity. Total factor productivity is estimated using both the Levinsohn-Petrin and Olley-Pakes methods augmented with the Ackerberg-Caves-Frazer correction, ensuring robustness to alternative productivity measurement techniques. In addition to three-dimensional static panel data models, dynamic specifications are also estimated using the System Generalized Method of Moments (GMM) approach to account for the persistence in productivity and potential endogeneity of R&D expenditures and other firm-level controls. The results consistently indicate that R&D expenditures have a positive and statistically significant effect on firms' total factor productivity across both static and dynamic specifications, even after controlling for firms' financial structure. The results of our investigation demonstrate that following the execution of a thorough series of sensitivity analyses with regard to alternative specifications of fixed effects and control variables for the static part, the findings suggest that once firm fixed effects are integrated into the estimation equation, the estimated coefficient on R&D expenditures maintains statistical significance only at the 10 percent level. According to the dynamic results, a positive and significant effect is observed in the relationship between R&D expenditure and TFP; however, due to the results of the Hansen test, these findings must be approached with caution. By relying on detailed firm-level micro data, this study contributes to the empirical literature on productivity dynamics in Türkiye. Strengthening R&D incentives and improving firms' financial resilience may advance the productivity enhancing impact of innovation oriented investments.

FİNANSAL KOŞULLAR ALTINDA AR-GE GİDERLERİ VE VERİMLİLİK: TÜRKİYE'DEKİ FİRMALARA YÖNELİK STATİK VE DİNAMİK PANEL VERİ ANALİZİ

ÖZET

Bu çalışma, Türkiye'de faaliyet gösteren firmalar için araştırma ve geliştirme (Ar-Ge) harcamaları ile firma verimliliği arasındaki ilişkiyi, firmaların finansal koşullarını açık biçimde dikkate alarak incelemektedir. Verimlilik göstergesi olarak toplam faktör verimliliği (TFV) kullanılmış; analiz tasarımı, hem gözlemlenemeyen firma, sektör ve zaman heterojenliğini kontrol eden statik panel veri modellerini hem de verimlilikteki sürekliliği ve potansiyel içsellik sorunlarını gözeten dinamik panel veri modellerini kapsamaktadır. İnceleme dönemi 2009–2023 olup, çalışma mikro düzeyde firma verileri ile sektör düzeyi bilgileri bir araya getiren zengin bir veri altyapısına dayanmaktadır.

Çalışmada kullanılan veri seti iki ana kaynaktan oluşturulmuştur. Birinci kaynak, firmaların Gelir İdaresi'ne yıllık olarak bildirdiği bilanço ve gelir tablosu verileridir; bu veri seti firma tanımlayıcılarını ve istihdam bilgilerini içeren bir referans tablo ile eşleştirilmiştir. İkinci kaynak ise Türkiye İstatistik Kurumu tarafından derlenen Yıllık Sanayi ve Hizmet İstatistikleri olup firmaların katma değer bilgilerini içermektedir. Bu iki kaynak, firmalara ait benzersiz tanımlayıcılar kullanılarak birleştirilmiş ve 2009–2023 dönemini kapsayan, firma ve sektör düzeyinde gözlem içeren dengesiz bir panel yapı elde edilmiştir. Tüm finansal değişkenler Üretici Fiyat Endeksi ile reel hale getirilmiş; modelde kullanılan değişkenler ağırlıkla doğal logaritma dönüşümüyle tanımlanmıştır.

Araştırma sorusu, Ar-Ge harcamalarındaki artışın firma TFV'sini artırıp artırmadığıdır. Bu ilişkiyi analiz edebilmek için, TFV'nin güvenilir biçimde ölçülmesi kritik görülmüş; bu nedenle TFV, üretim fonksiyonu yaklaşımı çerçevesinde birden fazla yöntemle tahmin edilmiştir. Çalışma, eşanlılık yanlılığı ve tanımlama problemlerine dikkat çekerek, klasik OLS ile üretim fonksiyonu tahmininin endojen girdi seçimleri nedeniyle yanlı sonuç verebileceğini vurgulamakta; bu nedenle vekil değişken temelli yöntemlere yönelmektedir. Bu bağlamda, Levinsohn–Petrin (LP) ve Olley–Pakes (OP) yöntemleri Ackerberg–Caves–Frazer (ACF) düzeltmesi ile birlikte uygulanmış; böylece hem OP-ACF hem LP-ACF TFV serileri üretilerek sonuçların verimlilik ölçüm tekniğine duyarlılığı kontrol edilmiştir. TFV dağılımlarının yıllar itibarıyla kutu grafikleriyle incelendiği ve medyanın görece istikrarlı seyrederken özellikle 2020 sonrası dağılımın bir miktar genişlediği; dolayısıyla firma verimliliğinde heterojenliğin önemini koruduğu ifade edilmektedir.

Ampirik strateji iki ana bloktan oluşmaktadır. İlk blokta, sabit etkiler içeren statik panel veri modelleri kurulmuştur. Temel statik modelde bağımlı değişken TFV (LP-ACF ve OP-ACF alternatifleriyle), temel açıklayıcı değişken ise firmaların Ar-Ge harcamalarıdır. Bu yapı, firma sabit etkileri, yıl sabit etkileri ve sektör sabit etkileri gibi bileşenlerle genişletilmiştir. Statik çerçevede ayrıca iki farklı alternatif model kullanılmıştır: (i) olası ters nedensellik veya eşanlılık riskini azaltmak amacıyla açıklayıcı değişkenlerin bir dönem gecikmeli değerleriyle tahmin; (ii) Ar-Ge'nin verimlilik etkisinin ihracat yoğunluğuna göre farklılaşıp farklılaşmadığını test etmek için, ihracat oranı yüzde 50'nin üzerinde olan firmaları tanımlayan bir gösterge ile Ar-Ge harcamasının çarpımından oluşan etkileşim terimi. İkinci blokta ise dinamik panel veri yaklaşımına geçilerek TFV'nin gecikmeli değeri modele eklenmiş ve potansiyel içsellik ile kalıcılık sorunlarına karşı Blundell–Bond Sistem GMM tahmincisi tercih edilmiştir. Araç değişken şişmesi riskine karşı collapsed ve non-collapsed araç seti karşılaştırmalı biçimde raporlanmış; tanı testleri olarak AR(1)-AR(2) seri korelasyon testleri ve Hansen aşırı tanımlama kısıtı testi sonuçları tartışılmıştır.

Statik analiz bulguları, modelin kontrol seti ve sabit etkiler yapısı değiştikçe Ar-Ge katsayısının düzey ve anlamlılığında belirgin farklılaşmalar olduğunu göstermektedir. Kontrol değişkeni ve sabit etki içermeyen en yalın doğrusal ilişkide Ar-Ge harcamalarının TFV ile pozitif ve istatistiksel olarak güçlü biçimde ilişkili olduğu raporlanmıştır: Ar-Ge'deki yüzde 1'lik artışın TFV'yi LP-ACF ölçümünde yaklaşık yüzde 0,101; OP-ACF ölçümünde yaklaşık yüzde 0,086 artırdığı belirtilmektedir. Yıl sabit etkileri eklendiğinde de katsayılar benzer biçimde pozitif ve anlamlı kalmakta (LP-ACF için yaklaşık yüzde 0,098; OP-ACF için yaklaşık yüzde 0,083) ve ortak zaman şoklarının bu korelasyonu bütünüyle açıklamadığı ima edilmektedir. Bununla birlikte, firma sabit etkileri modele dahil edildiğinde Ar-Ge katsayısı belirgin biçimde küçülmekte (LP-ACF için yaklaşık yüzde 0,024; OP-ACF için yaklaşık yüzde 0,022) ve ilişkinin bir kısmının zaman içinde değişmeyen firma özellikleriyle bağlantılı olabileceği anlaşılmaktadır. Bu desen, gözlemlenemeyen heterojenliğin (ör. yönetim kalitesi, organizasyonel yetkinlikler, teknoloji seviyesi) Ar-Ge ile verimlilik arasındaki basit korelasyonu şişirebileceğine işaret eden tipik bir bulgu yapısıdır.

Çalışma, finansal koşulları daha doğrudan yakalamak üzere kontrol değişkenlerini kademeli biçimde analize eklemektedir. Kontrol seti; toplam varlıklar, net satışlar, net kâr, toplam yabancı kaynak/varlık bileşenleri ve alacaklılar özkaynağı gibi bilanço ve gelir tablosundan türetilen değişkenlerden oluşmaktadır. Sabit etkiler olmaksızın yalnızca gözlemlenebilir finansal değişkenler kontrol edildiğinde Ar-Ge katsayısının pozitif ve anlamlı olduğu, ancak büyüklüğünün yalın modele göre gerilediği raporlanmaktadır (LP-ACF için yaklaşık yüzde 0,038; OP-ACF için yaklaşık yüzde 0,041). Bu aşamada kontrol değişkenlerinin işaretleri de ayrıntılı biçimde verilmektedir: Toplam varlıklar ve net satışlar katsayılarının negatif; net kârın katsayısının pozitif ve görece güçlü; bazı finansal kaldıraç/borçluluk göstergelerinin ise negatif ve anlamlı olduğu belirtilmektedir. Yıl sabit etkileri kontrol setine eklendiğinde katsayıların büyüklükleri büyük ölçüde korunmakta (Ar-Ge: LP-ACF yaklaşık yüzde 0,037; OP-ACF yaklaşık yüzde 0,040) ve zaman şoklarının eklenmesinin sonuçları kökten değiştirmediği ifade edilmektedir.

Ancak model, firma sabit etkileriyle birlikte kurulduğunda Ar-Ge katsayısı oldukça küçük bir düzeye inmektedir. Yıl ve firma sabit etkileri içeren kontrol değişkenli modelde Ar-Ge katsayısının yaklaşık yüzde 0,004 olduğu ve istatistiksel anlamlılığını yalnızca yüzde 10 düzeyinde koruduğu raporlanmaktadır. Yıl-firma-sektör sabit etkilerinin birlikte yer aldığı üç boyutlu sabit etkili spesifikasyonda da benzer bir sonuç elde edilmekte; Ar-Ge katsayısı yine yaklaşık yüzde 0,004 düzeyinde ve yüzde 10 anlamlılık seviyesindedir. Bu bulgu, Ar-Ge ile TFV arasındaki ilişkinin yönünün pozitif olmasına karşın, ilişki büyüklüğünün ve istatistiksel gücünün, heterojenlik kontrolleri sıkılaştıkça zayıfladığını göstermektedir. Çalışma, bu keskin düşüşü; gözlemlenemeyen firma ve sektör özelliklerinin ve finansal yapı farklılıklarının yalın korelasyonu açıklamada önemli rol oynayabileceği şeklinde değerlendirmekte ve Ar-Ge'nin tek başına büyük verimlilik sıçramaları yaratmasının her koşulda beklenmemesi gerektiğini vurgulamaktadır. Üç boyutlu sabit etkilerle dahi tam çözülemeyebilecek içsellik endişesi nedeniyle, açıklayıcı değişkenlerin bir dönem gecikmeli değerleriyle yapılan tahminler ayrıca raporlanmaktadır. Gecikmeli Ar-Ge katsayısının LP-ACF ölçümünde yaklaşık yüzde 0,024; OP-ACF ölçümünde yaklaşık yüzde 0,025 olduğu ve güçlü biçimde anlamlı çıktığı belirtilmiştir. Bu sonuç, cari dönem eşanlılık etkileri zayıflatıldığında dahi Ar-Ge'nin TFV ile pozitif ilişkisini koruduğunu, ancak etki büyüklüğünün model kurulumuna duyarlı olduğunu göstermektedir.

Çalışmanın bir diğer uzantısı, Ar-Ge-TFV ilişkisinin ihracat yoğunluğuna göre farklılaşıp farklılaşmadığının sınanmasıdır. Bunun için ihracat oranı yüzde 50'nin üzerinde olan firmaları temsil eden bir gösterge değişken ile Ar-Ge harcamasının etkileşimi modele eklenmiştir. Bu spesifikasyonda Ar-Ge katsayısının pozitif ve yüksek anlamlılıkla tahmin edildiği (LP-ACF yaklaşık yüzde 0,018; OP-ACF yaklaşık yüzde 0,020) raporlanırken; etkileşim teriminin işaretinin pozitif olmakla birlikte istatistiksel olarak anlamsız olduğu belirtilmektedir. Buna göre, örneklem ve tanım altında, Ar-Ge'nin TFV üzerindeki marjinal etkisinin yüksek ihracatçı grupta istatistiksel olarak farklılaştığına dair güçlü kanıt bulunmamaktadır. Aynı tabloda finansal kontrol değişkenlerinin işaret ve anlamlılık örüntüleri de sunulmakta; net kârın pozitif ve güçlü, toplam varlıklar ile bazı borçluluk/finansman göstergelerinin negatif yönde ilişkili olabildiği gösterilmektedir.

Dinamik analiz bölümünde, TFV'nin gecikmeli değerinin modele eklenmesiyle verimlilikteki kalıcılık yakalanmakta ve Ar-Ge'nin etkisi, potansiyel endojenlik göz önüne alınarak Sistem GMM ile tahmin edilmektedir. LP-ACF tabanlı dinamik sonuçlarda gecikmeli TFV katsayısının pozitif ve anlamlı olduğu (ör. yaklaşık 0,137–0,178 bandında raporlanan katsayılar) ve bu katsayının OLS ile within tahminleri arasında konumlandığı belirtilmektedir. Ar-Ge katsayısı dinamik spesifikasyonlarda da pozitif ve anlamlı raporlanmakta; ayrıca araç seti kurgusu (collapsed ve non-collapsed) karşılaştırmaları sunulmaktadır. Benzer desen OP-ACF tabanlı dinamik tabloda da görülmekte; gecikmeli TFV katsayısı pozitif ve anlamlı, Ar-Ge katsayısı pozitif ve anlamlıdır.

Dinamik model tanı testlerinde AR(1) testinin anlamlı, AR(2) testinin ise anlamsız çıkması; birinci fark hata terimlerinde beklenen birinci dereceden seri korelasyonun varlığına karşın ikinci dereceden seri korelasyon bulunmadığına işaret ederek moment koşullarının bu açıdan makul olduğunu göstermektedir. Bununla birlikte, Hansen aşırı tanımlama testi p-değerlerinin bazı spesifikasyonlarda istatistiksel olarak reddedici nitelikte olduğu raporlanmakta; bu nedenle araç geçerliliği konusunda temkinli yorum yapılması gerektiği özellikle vurgulanmaktadır. Çalışma, büyük örneklemlerde Hansen testinin hassasiyetine ve araç sayısına ilişkin literatür tartışmalarına atıfla, bu sonuçlardaki dinamik bulguların kesin çıkarımlarla yorumlanmasından kaçınılmasını gerektirdiğini belirtmektedir.

Genel olarak bulgular, Ar-Ge harcamaları ile firma TFV'si arasında pozitif yönlü bir ilişki bulunduğuna işaret etmektedir. Bununla birlikte, ilişkinin büyüklüğü ve istatistiksel gücü; sabit etkilerin kapsamına, finansal kontrol değişkenlerinin eklenip eklenmemesine, gecikmeli değişken kullanımına ve dinamik modeldeki araç seti tasarımına duyarlıdır. Statik modellerde sabit etkiler genişledikçe Ar-Ge katsayısının küçülmesi, heterojenlik ve seçim etkilerinin önemine işaret ederken; gecikmeli statik spesifikasyon ve dinamik GMM sonuçları, pozitif ilişkinin farklı kurulumlarda sürdüğünü göstermektedir. İhracat yoğunluğu ile Ar-Ge arasındaki etkileşimden elde edilen bulgular ise, tanımlanan eşik ve model altında, Ar-Ge'nin verimlilik etkisinin ihracatçı firmalarda sistematik olarak farklılaştığına dair güçlü bir kanıt sunmamaktadır.

Çalışma, yöntemsel açıdan TFV'nin hem LP-ACF hem OP-ACF yaklaşımlarıyla tahmin edilmesini ve bulguların iki ölçüm altında da benzer yön ve örüntüler göstermesini, sonuçların ölçüm tekniğine aşırı bağımlı olmadığının bir göstergesi olarak değerlendirmektedir. Ayrıca, üç boyutlu sabit etkilerle yüksek boyutlu heterojenliğin kontrol edilmesi ve dinamik panel yaklaşımıyla verimlilik kalıcılığının ve olası içselliğin ele alınması, Türkiye firma mikro verisi bağlamında Ar-Ge-verimlilik ilişkisine daha bütüncül bir çerçeve sağlamaktadır. Çalışma, literatürde özellikle gelişmekte olan ekonomilerde finansal kısıtlar ve firma yetkinliklerinin Ar-Ge'nin verimlilik getirilerini sınırlayabileceğine ilişkin bulgularla uyumlu bir biçimde, tahmin edilen etkilerin görece ılımlı büyüklükte olabileceğini not etmektedir.

Sonuç olarak, Ar-Ge'nin firma verimliliği açısından önemini koruduğu; ancak yalnız başına Ar-Ge harcaması artışının büyük verimlilik sıçramaları yaratmasının beklenmemesi gerektiği ifade edilmektedir. Bu çerçevede, Ar-Ge politikalarının etkinliğinin firmaların finansal dayanıklılığı, finansmana erişim koşulları ve uzun vadeli bilgi-teknoloji birikimini destekleyen tamamlayıcı unsurlarla birlikte değerlendirilmesi gerektiği vurgulanmaktadır. Türkiye bağlamında, sektörel heterojenlik ve finansal kısıtlar dikkate alındığında, Ar-Ge teşviklerinin tasarımının güçlendirilmesi ve hedeflemenin iyileştirilmesi; ayrıca firmaların emilim kapasitesini artıracak ve uzun vadeli yatırım ufkunu destekleyecek araçların önem taşıdığı belirtilmektedir. Dinamik tahminlerde Hansen testi kaynaklı temkin ihtiyacı da vurgulanarak bulguların özellikle nedensellik iddiaları bakımından ihtiyatlı yorumlanması gerektiği ifade edilmektedir.

1. INTRODUCTION

Productivity has been considered as a major component of competitive power and long term economic growth. In economic analysis, numerous types of productivity are utilized in order to assess firms, industries or countries' macroeconomic performances. Two parameters are generally used to measure productivity such as labor and capital productivity. While labor productivity regards output in terms of labor input, capital productivity accounts for the efficiency of capital use. However, these two metrics may not precisely grasp the process of production. Focusing only on labor and capital productivity does not fully reflect the overall effectiveness of production, since production is the result of the joint use of multiple inputs. For this reason, a more comprehensive measure, TFP, is used to capture the effectiveness of transforming inputs into output.

The effectiveness of firms in converting resources and inputs into final products and services is shaped not only by the scale of labor and capital employed, but also by differences in production techniques, organizational structures, and technological capabilities. Firms operating under similar input conditions may exhibit substantial variation in output levels, indicating that productivity differences cannot be fully explained by observable inputs alone. TFP captures these residual differences by reflecting how effectively all inputs are jointly utilized within the production process. As emphasized in the productivity literature, TFP serves as a comprehensive indicator of production efficiency, encompassing technological progress, managerial quality, and firm-specific practices that influence output beyond factor accumulation (Solow, 1957; Syverson, 2011).

A key channel through which firms enhance their ability to efficiently combine inputs is innovation. Improvements in production, new technologies adoption, and changes in organizational routines enable firms to reduce inefficiencies and operate closer to the production frontier. R&D activities support this process by facilitating knowledge creation, experimentation, and learning within firms. Through investing into the R&D, firms improve capabilities that foster innovation and improve production efficiency over time. Consequently, R&D expenditures are expected to contribute to higher levels of total factor productivity by strengthening the mechanisms through which innovation-driven efficiency gains are realized (Griliches, 1979; Hall and Mairesse, 1995; Crépon et al., 1998).

Taken together, these arguments suggest that examining the relation with R&D and TFP provides important insights into firms' production efficiency and innovation performance.

In this study, the main research question is how firms' R&D expenditures affect their productivity, measured by TFP, after controlling firm-level covariates with industry, firm, and time heterogeneity. Based on the theoretical and empirical literature, the hypothesis is that an increase in firms' R&D expenditures causes to an increase in their TFP.

To test this hypothesis, a three-dimensional fixed effects regression model is employed within a static panel data framework using firm-level data from Türkiye. Firm, year, and industry fixed effects are included in the model to account for multi-level heterogeneity. In addition, explanatory variables lagged by one-year are used as an alternative specification to mitigate potential endogeneity arising from contemporaneous correlation between unobserved factors affecting TFP and R&D expenditures. Moreover, an interaction term between the export ratio and R&D expenditures is incorporated as an extension of the baseline model to examine whether the effect of R&D expenditures depends on firms' export intensity.

After estimating the baseline three-dimensional static panel data models, the analysis is extended to a dynamic framework by including the lagged value of total factor productivity as an explanatory variable. This specification captures persistence in productivity and allows for dynamic adjustment effects. Given the potential endogeneity of R&D expenditures and other firm-level controls, the empirical framework is estimated using the System GMM approach, which combines equations in levels and relies on internal instruments.

To address concerns related to instrument proliferation, two alternative instrument structures are considered: a collapsed and a non-collapsed version of the dynamic model. The comparison of these specifications enables an assessment of the robustness of the estimated dynamic relation with R&D expenditures and TFP to different instrument designs.

Our findings show that after conducting a comprehensive set of sensitivity checks with respect to alternative specifications of fixed effects and control variables for the static part, the results indicate that once firm fixed effects are incorporated into the estimation equation, the estimated coefficient on R&D expenditures remains statistically significant only at the 10 percent level. According to the dynamic results, a positive and significant effect is observed in the relation between R&D and TFP; however, due to the results of the Hansen test, we must approach these findings with caution.

This thesis contributes to the existing literature through comprehensively analyzing the relationship between R&D expenditures and productivity in Turkish firms at the firm and industry levels. By combining advanced productivity estimation techniques with both static and dynamic panel data methods, the study offers consistent evidence on R&D role in shaping firm-level productivity. The use of three-dimensional fixed effects and dynamic System GMM allows for a comprehensive treatment of unobserved heterogeneity and endogeneity concerns. In addition, the analysis explores heterogeneity in R&D effects on productivity by considering firms' export activity, thereby providing new insights into the channels through which R&D expenditures affect productivity.

This study is organized into five main chapters. After the Introduction part, Chapter 2 presents the Literature Review part gives an economic theory of the relationship between R&D - TFP, then surveys relevant studies distinguishing between firm-level empirical work and country-level empirical work, and concludes with highlighting how this study differs from the current literature. Chapter 3 gives the datasets and methodological framework, including a detailed description of the dataset, alternative approaches to productivity estimation, and the empirical strategies adopted in both static and dynamic panel settings. This chapter also introduces extensions of the baseline model. Chapter 4 represents the empirical findings and gives a structured discussion of the findings obtained from the static and dynamic estimations with panel data. The outcomes are evaluated in terms of their consistency with theoretical expectations and existing empirical evidence. Lastly, fifth chapter provides the summary of the main findings.

2. LITERATURE REVIEW

This part represents a structured empirical literature review examining relation with R&D activities and TFP. It is organized through four sub-sections. First sub-section gives an economic theory on R&D role in productivity. The second sub-section focuses on firm-level studies, emphasizing micro-level evidence on how R&D expenditures, innovation activities, and knowledge spillovers affect productivity across firms. Third sub-section presents country-level frameworks, which explore the macroeconomic relation with R&D investment, productivity growth, and economic performance across different country groups. The fourth sub-section summarizes the methodological approaches adopted in the literature, highlighting the common estimation techniques used to measure TFP and address issues such as endogeneity, heterogeneity, and measurement error.

2.1 Economic Theory on the Role of R&D in Productivity

Economic theory offers fundamental theoretical foundations for expecting R&D expenditures to affect TFP. TFP represents the effectiveness where production inputs such as labor and capital are coverted to output, commonly interpreted as a measure of technological progress and production efficiency. Since R&D activities are designed to generate new knowledge, improve production processes, and foster innovation, they are naturally expected to enhance productivity beyond what can be explained by input accumulation alone.

In the neoclassical growth framework, technological progress is regarded as an exogenous parameter takes the production function to the up over time. While this approach acknowledges the importance of technology for productivity growth, it does not explain how technological change is generated. This limitation is addressed by endogenous growth theory, which explicitly models technological progress as the outcome of intentional investment decisions, particularly in R&D activities.

A central contribution to endogenous growth theory is provided by Romer (1990), who models technological change as the result of purposeful R&D investment undertaken by profit-maximizing agents. In this manner, R&D expenditures causes knowledge capital accumulation in creation of new ideas, designs, and technologies. Knowledge is characterized as a non-rival and partially non-excludable input, meaning that once an idea is created, it can be used by multiple firms without being depleted. This feature generates returns to scale as increasing, even if firms operate under constant returns to scale individually. As a result, sustained growth in productivity and TFP can be achieved through continuous investment in R&D (Romer, 1990).

Romer’s model further emphasizes knowledge spillovers as a primary metric where R&D affects productivity. Although firms invest R&D so as to rise own productivity, part of the generated knowledge diffuses to other firms through imitation, labor mobility, trade linkages, and informal networks. Consequently, differences in R&D intensity across firms or countries lead to persistent productivity differentials, as reflected in TFP measures.

Complementing the endogenous growth perspective, the Schumpeterian growth framework highlights innovation and creative destruction as the driving forces of productivity growth. Building on the original ideas of Schumpeter (1934, 1942), modern Schumpeterian models formalize the notion that economic growth arises from a sequence of quality-improving innovations that replace outdated technologies. In the seminal model by Aghion and Howitt (1992), firms execute R&D so as to make innovations that increase the productivity of existing technologies. Each successful innovation raises TFP by improving production efficiency while simultaneously rendering older technologies obsolete.

Within the Schumpeterian framework, R&D affects productivity through both innovation and reallocation mechanisms. First, R&D generates new technologies that directly increase firm-level productivity. Second, innovation-driven competition reallocates resources toward more productive firms, as innovative firms expand and less productive firms contract or exit the market. This reallocation process amplifies the R&D impact on aggregate productivity and is consistent through observed firm-level productivity dynamics documented in empirical studies (Aghion & Howitt, 1992).

Both endogenous growth and Schumpeterian theories also emphasize the role of incentives and market structure in shaping decisions in R&D expenditures. Firms engage in R&D when expected innovation rents outweigh the associated costs. Temporary monopoly profits, protected by imperfect competition, linking productivity gains directly to R&D expenditures (Romer, 1990; Aghion & Howitt, 1992). Therefore, observed R&D investment reflects firms' expectations about future productivity improvements.

From a production function perspective, R&D can be interpreted as an intangible form of capital that complements labor and physical capital. Incorporating R&D or knowledge capital into the production function provides a theoretical justification for modeling R&D as a determinant of TFP or TFP growth. Differences in productivity among firms or countries can thus be examined by variations in knowledge accumulation, innovation intensity, and technology adoption, rather than solely by differences in observable inputs.

Overall, economic theory consistently predicts a positive relation with R&D expenditures and TFP through multiple, mutually reinforcing channels, including knowledge accumulation, innovation, spillovers, creative destruction, and resource reallocation. These theoretical mechanisms provide a strong foundation for the empirical analyses examined in this work and justify the expectation that when R&D expenditures rise, leading to productivity to rise at both the firm and country levels.

2.2 Firm-Level Studies

Dai et al. (2022) investigate the relation with TFP and R&D by decomposing R&D into two components: internal R&D and collaboration of R&D. Knowledge spillovers are also examined as a potential contributor to productivity. The study employs firm-level static panel data for firms located in Shanghai, using annual survey data. The findings shows that R&D capital has a positive and statistically significant effect on productivity. TFP is estimated using two alternative methods, namely the Olley and Pakes (OP) and Levinsohn and Petrin (LP) approaches. A comparison of TFP estimates obtained from both methods shows consistent results, with R&D contributing positively and significantly to TFP. Control variables include granted patents, R&D-related subsidies, employee education levels, export revenues, employment in R&D departments, and inter-firm R&D collaboration.

Mamatzakis et al. (2023) show that R&D causes positively to TFP growth in Greek industries. The study applies a novel LIML estimation technique, which enables the authors to address endogeneity and model misspecification issues. Financial ratios, specifically liquidity and solvency ratios, are incorporated as control variables, both of which are found to contribute positively to TFP. The analysis further examines heterogeneity across firm sizes, distinguishing between small, medium, and large firms. The findings suggest that small firms exhibit higher TFP levels and higher R&D expenditures compared to larger firms.

Kané (2022) evaluates eight different methods for estimating TFP in construction firms in France, including Olley and Pakes (OP), Levinsohn and Petrin (LP), Wooldridge, Ackerberg-Caves-Frazer (ACF), fixed effects, instrumental variables (IV), generalized method of moments (GMM), calibration, and data envelopment analysis (DEA). The Wooldridge estimator yields the highest TFP estimates, while the fixed effects estimator produces the lowest. Based on the methodological considerations, the study concludes that the ACF estimator provides the most suitable TFP estimates for the construction firms.

Hall and Mairesse (1995) estimate productivity using a Cobb–Douglas production function that includes capital, labor, and R&D capital (knowledge capital) as inputs. The analysis relies on the firm-level panel data for French manufacturing firms over the period 1980–1987. The findings represents that the duration over which R&D expenditures are accumulated significantly affects the estimated relationship with R&D and productivity, with longer R&D series yielding a stronger correlation with productivity growth.

Wakelin (2001) analyzes R&D impact on productivity growth using a Cobb–Douglas production function and data for 170 UK firms which are firm level. The results presents that R&D has a positive and statistically significant effect for the productivity growth. Firms further are classified as innovative or non-innovative, and the findings reveal that innovative firms experience returns which are higher to R&D than non-innovative ones.

Chen et al. (2020) examine the relationship with public R&D expenditure and TFP using a Cobb–Douglas production function and firm-level panel data. The findings show that increases in R&D expenditures lead to higher firm productivity. Time and sector fixed effects are integrated in the panel data model to control unobserved heterogeneity.

Hu (2001) investigates the R&D and productivity relation in China by distinguishing through government and private R&D expenditures. TFP is estimated using a Cobb–Douglas production function. The findings show that private R&D expenditures have a direct and significant impact on productivity, while government R&D expenditures indirectly affect firm productivity through their influence on private R&D. Consequently, both types of R&D expenditures contribute to firms’ productivity growth.

Beule and Narayanan (2016) analyze firm-level panel data from eight selected industries in India to estimate TFP using a Cobb–Douglas production function, where value added used as the output. In the fixed effects model, the share of R&D is integrated as a control parameter alongside trade intensity and industry scale. The results for the manufacturing sector indicate that one percentage rise in the share of R&D contributes to 1.4 percentage rise in TFP growth. This effect rises to 6 percent in the chemical industry and 5 percent in the machinery industry, which are characterized by higher innovation intensity and higher productivity relative to the manufacturing sector as a whole.

Bennett et al. (2017) examine the effect of informative stock prices on firm productivity. After using TFP as the productivity measure, estimated through the LP method with ACF correction, the analysis shows a positive relation with informative stock prices and productivity. Instrumental variable techniques and difference-in-differences methods are employed to identify the causal effects and to examine the exogenous shocks effects to stock prices. The results indicate that the strength of this relation varies among firms depending size, performance, and risk characteristics.

Hann et al. (2019) utilize firm-level data and estimate TFP using the LP method for manufacturing sector. The study demonstrates that TFP estimates vary across different interquartile ranges of firms. A relationship is established between productivity distribution and accounting information quality, highlighting the importance of financial reporting for informing investors about firm productivity. Total revenues are used as an output measure in TFP estimation. In the fixed effects model, productivity distribution is treated as a dependent variable, while financial reporting quality is included as an explanatory variable. Control variables include fixed and sunk costs as well as measures of market rivalry. Time fixed effects are integrated, and standard errors are clustered in industry and time levels. The results suggest that industries with higher financial giving quality low productivity distribution, with stronger effects observed in environments characterized by higher exogenous financing density.

Mitra et al. (2016) investigate whether information and infrastructure and communication technology (ICT) affect productivity and technical efficiency (TE) in Indian manufacturing firms between 1994 and 2010. TFP is estimated using firm-level data and ordinary least squares (OLS). R&D expenditure intensity is included as a control variable, along with trade intensity and firm size. The analysis employs OLS, panel cointegration, and system GMM methods. Sectoral analyses reveal that the impact is stronger in textile, metal and chemical industries. The value added is utilized as an output measure, and the data are normalized using the price index which is wholesale. The estimated elasticities for overall infrastructure with respect to TFP and TE are 0.3 and 0.1, respectively, with consistent results obtained from system GMM estimations. R&D-intensive sectors, particularly chemicals and machinery, are found to be the most productive.

Ballot et al. (2001) analyze the firm-level data from France and Sweden for 1987–1993 in order to analyze the relation with the human capital, R&D expenditures, and productivity. A Cobb–Douglas production function is specified through value added as an output, physical capital, labor, human capital stock, and technology as inputs. The determinants of TFP growth are estimated using OLS, fixed effects, random effects, and system GMM methods. The results show that training and R&D expenditures have a stronger productivity effect compared to the other inputs, but the magnitude of the effect varies across countries. Interaction parameters with training and R&D are included under the baseline model, but these results are not robust across the estimation methods. Overall, no significant impact on productivity growth is found when all methods are jointly considered.

Bağır and Seven’s (2021) study reveals that firms' productivity performance is closely related not only to technological or scale factors, but also to financial structure and access to finance conditions. The study emphasizes that companies' borrowing capacity, liquidity position, and financial fragility indicators are important factors determining efficiency in the production process; it states that companies are constrained to lower levels of efficiency in resource allocation, particularly during the periods of intense financial constraints. The findings show that financially stronger firms are more resilient to productivity losses and can adapt more effectively to shocks. In this context, the study points to the need to include financial condition variables in firm-level productivity analyses, providing a strong theoretical and empirical basis for empirical approaches that consider TFP alongside the financial indicators.

2.3 Country-Level Studies

Guloglu and Tekin (2012) analyze the data from some high-income countries for the years 1991–2007 to examine the relation with R&D expenditures, patent activity, economic growth. Gross domestic R&D expenditures and number of patents are used to represent innovation, while GDP measures economic growth. Panel Granger causality tests are conducted using both fixed effects and GMM estimations, with Wald tests employed for the inference. Given the relatively long-time dimension of the panel, fixed effects results are emphasized. The findings indicate multiple significant causal relationships among R&D, patents, and GDP, with some causal links identified exclusively under GMM or fixed effects estimation. The findings show that innovation dynamics are realized through both technology and demand-related factors within a balanced framework.

Ortega and Marin (2011) examine the bidirectional relation with R&D and productivity utilizing panel data from 65 countries over the period 1965–2005. TFP is derived from a Cobb–Douglas production function incorporating capital, labor, and experience, where the experience represents the accumulated knowledge stock. The empirical model includes socioeconomic conditions, investment ratios, trade openness, inflation, R&D expenditures, GDP per capita, and foreign direct investment. The system GMM model is utilized in order to solve endogeneity concerns. The results reveal a direct impact of R&D expenditures per capita on TFP significantly, while indirect effects are not statistically significant. The magnitude of the effect varies across income groups, with high-income countries experiencing higher returns to R&D.

Adetutu and Ajayi (2020) analyze the relation with R&D expenditures and productivity for the agricultural sector using data from 30 countries over the period 1981–2011. R&D expenditures are decomposed into domestic and foreign components. The results show that R&D which is domestic impact on TFP stronger than R&D which is not domestical, emphasizing the importance of increasing domestic R&D to improve agricultural efficiency in Sub-Saharan African countries.

Herzer (2022) examines the effects of domestic R&D expenditures and R&D spillovers on TFP using panel data from 82 developing countries between 1990 and 2016. Countries are classified according to the income level. The results show that domestic R&D expenditures have a larger effect on TFP than foreign R&D spillovers across all income groups, with stronger effects examined in middle-income ones rather than low-income ones.

Coccia (2009) investigates the optimal level of R&D expenditures required to sustain long-term growth in productivity in member states of the European Union and candidate countries. The panel dataset includes R&D as a percentage of GDP, labor efficiency, employment ratios, and GDP per capita. The results describe that while R&D investment affects productivity growth positively, the effect diminishes beyond an optimal threshold. The optimal R&D investment level is estimated to be approximately 2.5 percent of GDP, beyond which marginal productivity gains decline. Under stable socioeconomic and geopolitical conditions, this level of R&D investment is found to make maximum long-run productivity growth.

2.4 Contribution

The previous sections show that the existing literature provides extensive evidence on the relationship with productivity and R&D expenditures for firm and country levels. This analysis provides to the literature in several important courses. First, the most existing studies control for firm and time fixed effects, while this study additionally incorporates industry fixed effects, allowing for a more comprehensive control of sector-specific heterogeneity. This is constructed by combining a dataset consisting of balance sheet and income statement which are firm level with a reference table from the Revenue Administration, and then the dataset, Annual Industry and Service Statistics, is merged obtained from the TURKSTAT. Second, to address potential endogeneity concerns, the empirical framework is extended by incorporating lagged explanatory variables to mitigate potential contemporaneous correlation between unobserved factors affecting TFP and the variables of interest. Third, beyond static fixed effects estimations, the analysis employs dynamic model estimated using the system GMM, enabling the identification of productivity dynamics while accounting for persistence and simultaneity. Finally, the dataset used in this study is unique in that it combines detailed firm-level balance sheet information with industry-level statistics for Turkish firms over a 15-year period (2009-2023), providing a rich empirical setting for analyzing the R&D and productivity relationship.

3. DATA AND METHODOLOGY

This part provides the data and empirical methodology utilized to analyze the relation with firm-level R&D expenditures and productivity. The main part starts with a describing the data, including sources of the data, sample construction, and variable definitions used in the analysis. The first subsection focuses on the structure of the dataset and the key variables derived from the firm-level information. The subsequent main section presents the methodology utilized to estimate TFP, describing the underlying production function framework and the estimation approach adopted. The final main section introduces the empirical strategy of the study. Within this section, the baseline static fixed effects model is presented first, followed by several model extensions and robustness checks. The last subsection introduces a dynamic panel model specification that accounts for productivity persistence and potential endogeneity issues.

3.1 Description of Data

3.1.1 Data Sources and Sample Construction

In this thesis, two main data sources are utilized to examine the relation of firms’ R&D expenditures and productivity. The first dataset consists of balance sheet and income statement data which are firm level reported annually to the Revenue Administration, together with a reference table that includes firm identifiers. The second dataset is obtained from the Turkish Statistical Institute (TURKSTAT) and corresponds to the Annual Industry and Service Statistics. The combined dataset covers the period from 2009 to 2023 for firms operating in Türkiye. These datasets are provided to the Central Bank of the Republic of Türkiye by TURKSTAT and the Revenue Administration.

The analysis is based on the firm-level financial statements merged with a reference table that contains information on the number of employees. These two datasets, covering the years 2009–2023, are merged using firms’ unique tax identification numbers. Several filtering procedures are then applied to construct the final sample. In the beginning of the process, the raw dataset contains 10,918,495 observations over 15 years, corresponding to 1,670,756 unique firms.

First of all, firms with one or fewer employees are excluded from the data. This restriction serves two purposes. One of these purposes is that too small firms are possibly to exhibit irregular reporting behavior and extreme values, which may distort empirical results. In addition, several variables are expressed in logarithmic form, and observations with zero or missing employment cannot be log-transformed. Therefore, restricting the sample to firms with more than one employee ensures both economic relevance and consistency with the empirical specification. This restriction removes 4,431,331 observations from our sample.

Second, firms are required to have data for at least two years in order to reduce distortions arising from temporary market entries and exits. Firms observed in only a single year may introduce excessive noise into the estimation of dynamic relationships. Requiring at least two observations allows firm behavior over time to be significantly analyzed. However, to avoid losing information on new firms entering the market in the final year, all firms with more than one employee are retained for the year 2023, even if they are observed only in that year. After applying this rule, the dataset contains 6,381,601 observations.

Third, firms with non-positive net sales or current assets are excluded to eliminate inactive or financially meaningless observations. Positive net sales ensure that firms are economically active, while positive current assets indicate ongoing operational capacity. Since productivity and financial performance indicators are meaningful only for active firms, this restriction improves the reliability of the estimated relationships. After this step, the sample is reduced to 6,130,066 observations without changing the number of firms.

The Annual Industry and Service Statistics dataset is then merged using unique tax identification numbers in order to incorporate information on firms' value added. Firms with non-positive value added are subsequently excluded, as productivity measures require positive value added by definition. After this final restriction, the dataset consists of 5,528,568 observations.

The resulting panel is unbalanced, as firms enter and exit the sample over time. In the study by Yang et al. (2024), it is stated that given the unbalanced structure, fixed effects specifications are particularly appropriate for controlling time-invariant unobserved heterogeneity in panel settings with entry and exit dynamics.

After cleaning the data, all variables are normalised using the Producer Price Index (PPI) to obtain real values. Then, all the variables are transformed into the natural logarithms. Descriptive statistics for all variables utilized in the estimation sample are reported in Table 3.1.

Table 3.1 : Descriptive Statistics.

Variable	Mean	Median	Standard Deviation	Minimum	Maximum	Number of Observation
Total factor productivity by Levihnson and Petrin method with ACF correction	3.37	3.40	1.04	-14.12	12.48	5,108,515
Total factor productivity by Olley and Pakes method with ACF correction	3.04	3.06	1.04	-14.60	12.86	5,108,515
Natural logarithm of R&D Expenditures	5.67	6.01	2.69	-12.42	16.14	74,211
Natural logarithm of total assets	7.96	7.98	1.96	-12.42	19.27	5,322,267
Natural logarithm of net sales	8.11	8.13	2.01	-12.42	19.52	4,739,277
Natural logarithm of net profit	5.03	4.91	1.92	-12.42	17.36	4,185,377
Natural logarithm of total foreign resources	7.82	7.86	1.95	-12.42	19.52	5,345,713
Natural logarithm of creditors’ equity	6.74	6.93	2.25	-12.42	18.20	4,653,807

3.2 TFP Estimation Methods

To formalize the concept of TFP, consider a standard Cobb–Douglas production function in which output is produced using capital and labor inputs:

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{B}, \tag{3.1}$$

where

- Y denotes the output for the firm i at time t,
- A denotes the technology component for the firm i at time t,
- K shows the capital for the firm i at time t,
- L shows the labor for the firm i at time t, and
- α and B represent a weight component of capital and labor, respectively.

After taking the natural logarithm of the Cobb-Douglas production given in the equation 3.1, the new form of equation takes the following form:

$$\ln(Y_{it}) = \ln(A_{it}) + \alpha \ln(K_{it}) + B \ln(L_{it}), \tag{3.2}$$

where

- $\ln(Y_{it})$ denotes the natural logarithm of the output for the firm i at time t,
- $\ln(A_{it})$ denotes the natural logarithm of technology component for the firm i at time t,
- $\ln(K_{it})$ denotes the natural logarithm of the capital for the firm i at time t with a coefficient of α,
- $\ln(L_{it})$ denotes the natural logarithm of the labor for the firm i at time t with a coefficient of B.

The equation (3.2) can be written as using lowercases rather than writing natural logarithms of the parameters. The linear equation takes place as below in the equation (3.3):

$$y_{it} = B_0 + \alpha\, k_{it} + \mathrm{B}\, l_{it} + \varepsilon_{it}, \tag{3.3}$$

from this equation, it can be seen that $\ln(A_{it})$ written as $\ln(A_{it}) = B_0 + \varepsilon_{it}$ in the linear form. ε_{it} includes both observed and unobserved shocks by firms. Therefore, ε_{it} is separated into two parts such that μ_{it} to represent observed shocks, while ν_{it} to represent unobserved shocks. Then, the new equation takes the following form:

$$y_{it} = B_0 + \alpha k_{it} + \mathrm{B} l_{it} + \mu_{it} + \nu_{it}, \tag{3.4}$$

where

- y_{it} denotes the natural logarithm of the output for the firm i at time t,
- k_{it} denotes the natural logarithm of the capital for the firm i at time t with a coefficient of α,
- l_{it} denotes the natural logarithm of the labor for the firm i at time t with a coefficient of B,
- μ_{it} denotes the observed shocks for the firm i at time t,
- ν_{it} denotes the unobserved shocks for the firm i at time t.

Measuring total factor productivity using OLS leads to biased and inconsistent results because input choices are correlated with unobserved productivity shocks. Within the framework of a Cobb–Douglas production function, firms observe their productivity when choosing inputs such as capital and labor. As a result, these inputs are endogenous, giving rise to simultaneity bias when OLS is applied.

To address this issue, the literature has proposed several alternative ways to estimate production function. These include fixed effects estimators, instrumental variable and GMM methods (Blundell and Bond, 1999), proxy variable approaches such as Olley and Pakes (1996) and Levinsohn and Petrin (2003), as well as control function methods developed by Wooldridge (2009). A further refinement is provided by Ackerberg et al. (2015), who highlight the identification problems in traditional OP and LP estimators arising from functional dependence between labor inputs and proxy variables.

In particular, while the OP and the LP methods successfully address simultaneity bias by using investment and intermediate inputs, respectively as proxies for unobserved productivity, they may suffer from weak identification of labor coefficients due to the timing assumptions. The ACF correction modifies these assumptions and improves the identification of production function parameters without altering the underlying proxy variable framework.

In this study, total factor productivity is estimated using the Levinsohn–Petrin and Olley–Pakes approaches augmented with the Ackerberg–Caves–Frazer correction. The estimation follows the unified implementation framework proposed by Rovigatti and Mollisi (2018), which provides a consistent and transparent application of modern proxy variable methods for production function estimation and facilitates the implementation of the OP-ACF and LP-ACF estimators in the empirical analysis.

Figure 3.1 presents the distributions of productivity estimates obtained using the alternative methods, including OLS, fixed effects, OP, OP-ACF, LP, and LP-ACF. For comparison, labor productivity, which is defined as value added per worker, is also estimated. Across all measures, the distributions exhibit left-skewness, indicating the presence of low-productivity firms in the sample.

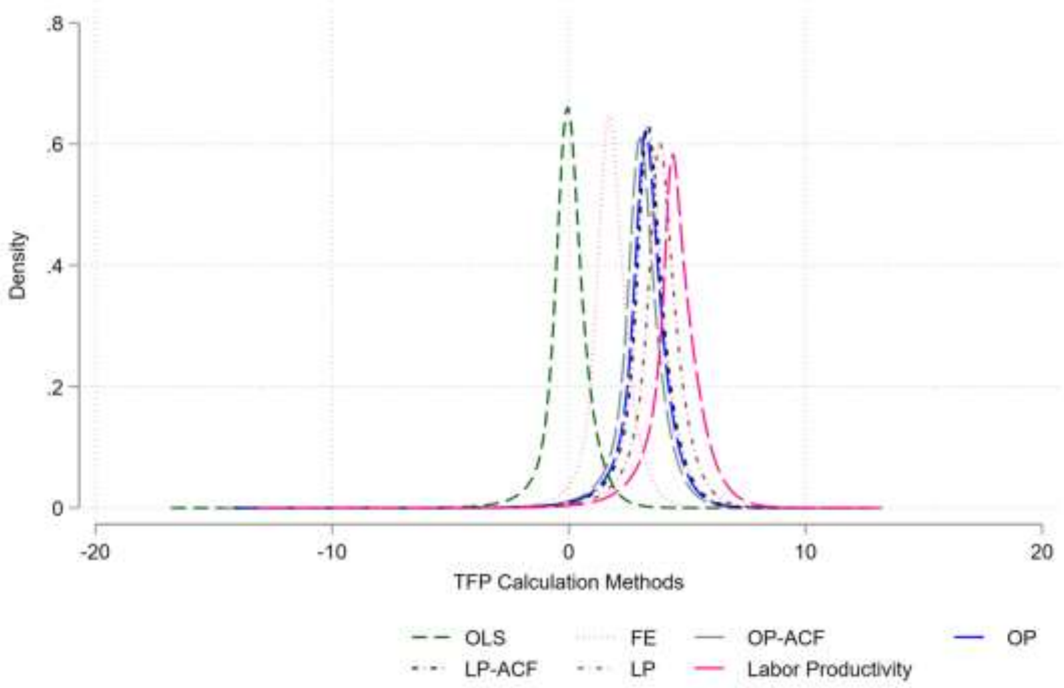

Figure 3.1 : TFP Calculation with Different Methods.

Table 3.2 presents the descriptive statistics of alternative productivity measures derived from different estimation methods, while Figure 3.1 illustrates the kernel density distributions of these measures.

The purpose of presenting multiple productivity estimates at this stage is to provide a comparative overview of their distributional properties rather than to indicate that all measures are subsequently utilized in the regression model. In the empirical model that follows, the focus is placed on TFP measure utilizing the OP-ACF and LP-ACF methods, which are consistent with the adopted production function framework and address identification issues emphasized in the literature. The remaining productivity measures are reported for benchmarking considerations, allowing for a transparent comparison across the alternative estimation approaches.

Table 3.2 : Descriptive Statistics for Productivity Estimations.

Variable	Mean	Median	Standard Deviation	Minimum	Maximum	Number of Observation
TFP by OLS	-0.002	-0.001	0.876	-16.802	9.164	4,980,982
TFP by FE	1.763	1.761	0.878	-14.982	11.577	4,980,982
TFP by OP-ACF	3.035	3.060	1.038	-14.597	12.862	5,108,515
TFP by OP	3.264	3.296	1.039	-14.155	12.808	5,108,515
TFP by LP-ACF	3.371	3.397	1.036	-14.122	12.478	5,108,515
TFP by LP	3.847	3.888	1.068	-13.081	12.552	5,108,515
Labor Productivity	4.487	4.502	1.156	-13.183	13.241	5,362,689

Figure 3.2 presents the yearly distribution of total factor productivity measured utilizing the Levinsohn–Petrin approach with Ackerberg–Caves–Frazer correction (LP-ACF) over the period 2009–2023. The boxplots illustrate the evolution of the central tendency and dispersion of firm-level productivity across years, excluding extreme outliers. Overall, TFP values estimated by the LP-ACF method range approximately between 1 and 6 throughout the sample period.

The figure suggests that while the median level of productivity remains relatively stable over time, there are noticeable variations in the dispersion of TFP across years. This indicates the presence of heterogeneity in firm-level productivity dynamics, which motivates the utilization of panel data methods that explicitly controlling firm-specific and time-specific effects in the subsequent empirical analysis.

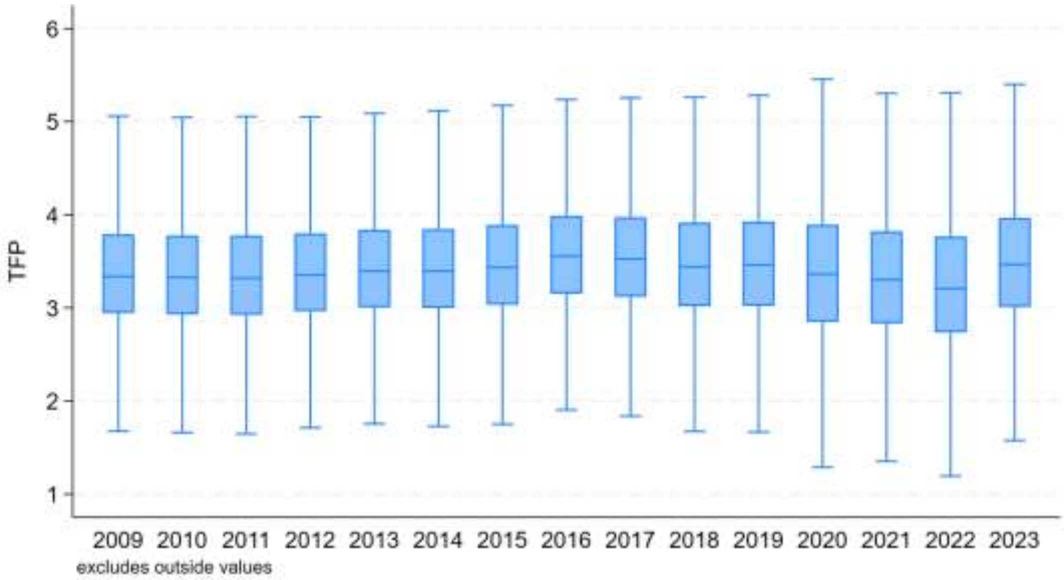

Figure 3.2 : Yearly Distribution of TFP Calculation by Using LP-ACF.

Figure 3.3 presents the yearly distribution of total factor productivity estimated using the Olley–Pakes method with the Ackerberg–Caves–Frazer correction (OP-ACF) over the period 2009–2023. The boxplots illustrate the evolution of firm-level productivity across years after excluding extreme outliers. TFP values estimated by the OP-ACF method range approximately between 0 and 5.5 throughout the sample period.

Similar to the LP-ACF estimates, the median level of productivity estimated with OP method with ACF correction remains relatively stable over time, while the dispersion of TFP exhibits variation across years. This pattern reflects permanent heterogeneity for the productivity in firm level and supports the use of panel data approaches that controlling unobserved firm-specific and time-specific impacts in the empirical analysis.

A comparison of Figures 3.2 and 3.3 indicates that the LP-ACF and the OP-ACF productivity estimates display similar distributional patterns over time from 2009 and 2023. The boxplots display the median, interquartile range, and overall dispersion of TFP values while excluding extreme outliers. Across most years, the median TFP remains relatively stable around similar levels, suggesting limited structural shifts in central productivity trends. However, after 2020, the distribution appears slightly more dispersed, with longer lower tails and wider variability, indicating increased heterogeneity among firms. Despite these fluctuations, the overall interquartile range remains broadly consistent over time, implying that the core productivity distribution is relatively stable.

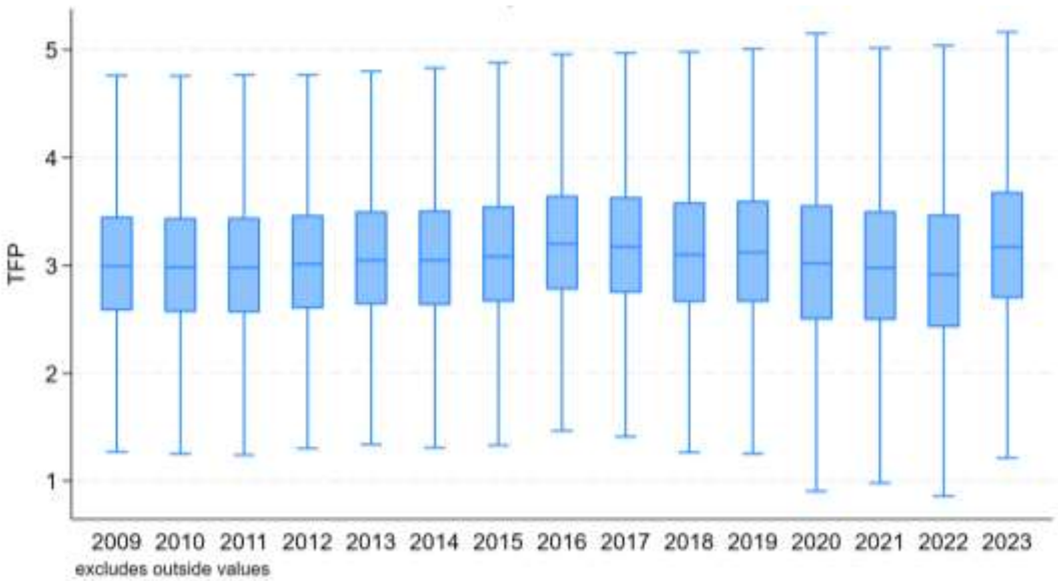

Figure 3.3 : Yearly Distribution of TFP Calculation by Using OP-ACF.

3.3 Empirical Methods

3.3.1 Static Fixed Effects Model

To analyze the impact of R&D expenditures on productivity in firms, a three-dimensional static fixed effects panel data model is employed. The baseline specification estimates TFP utilizing R&D as a main explanatory variable, with some financial control variables. For the baseline specification, TFP is measured utilizing both for the LP-ACF and the OP-ACF methods.

The main empirical model is given as:

$$TFP_{ijt} = B_0 + \alpha\, RD_{ijt} + \mathrm{B}X_{ijt} + \gamma_i + \delta_j + \lambda_t + \varepsilon_{ijt}, \tag{3.5}$$

where TFP_{ijt} denotes the total factor productivity of firm i operating in industry j at time t, RD_{ijt} represents firms' R&D expenditures of firm i operating in industry j at time t, and X_{ijt} is a vector of control parameters derived from firms' financial statements of firm i operating in industry j at time t. Firm fixed effects γ_i control for time-invariant unobserved firm characteristics, industry fixed effects δ_j capture sector-specific heterogeneity, and year fixed effects λ_t for common macroeconomic shocks.

Note that firm and industry fixed effects cannot be separately identified if firms do not change industries over time. In that case, the industry fixed effects reduce to averages of the firm fixed effects. However, in our sample, firms do change industries over time. Therefore, the industry fixed effects are identified from the switchers. The error term ε_{ijt} captures idiosyncratic disturbances that are assumed to be heteroskedastic and autocorrelated within firms.

3.3.2 Extensions

In addition to the baseline specification, two alternative variants are considered for robustness checks. First, to address potential endogeneity concerns arising from simultaneity and reverse causality, the model is extended by including one-period lagged values of the explanatory variables. The lagged specification takes the following form:

$$TFP_{ijt} = B_0 + \alpha\, RD_{ijt-1} + \mathrm{B}X_{ijt-1} + \gamma_i + \delta_j + \lambda_t + \varepsilon_{ijt}, \tag{3.6}$$

where lagged R&D expenditures and control variables reduce the correlation between current productivity shocks and firms' input decisions.

Second, to capture the potential heterogeneity in the relationship between R&D expenditures and firm productivity with respect to firms' export intensity, this study constructs an export intensity indicator and an associated interaction term. Export intensity is measured as the ratio of real sales abroad to real gross sales.

Based on this measure, a binary indicator variable, high export intensity, is defined, taking the value of one for firms whose export intensity exceeds 50 percent, and zero otherwise. This threshold is employed to distinguish firms that are predominantly export-oriented from those whose sales are primarily domestic.

To analyze if the productivity impacts of R&D expenditures differ between high-export and low-export firms, an interaction term is constructed by multiplying real R&D expenditures with the high export intensity indicator. This interaction term is incorporated into the empirical model as an alternative to the primary model, allowing marginal impact of R&D on TFP to vary according to firms' export orientation.

By doing so, the analysis explicitly tests whether the export-intensive firms benefit differently from R&D investments compared to firms with lower exposure to international markets. The equation (3.7) gives the integration of the interaction term as follows:

$$TFP_{ijt} = B_0 + \alpha\, RD_{ijt} + \mathrm{B}X_{ijt} + \mu\, Export_{ijt} * RD_{ijt} + \varepsilon_{ijt}, \tag{3.7}$$

where $Export_{ijt} * RD_{ijt}$ represents the interaction term for firm i executing in sector j at year t.

3.3.3 Dynamic Fixed Effects Model

After estimating the static panel data models, the analysis is extended to dynamic framework so as to capture persistence in firm-level productivity to further address potential endogeneity concerns. For this purpose, two-step System GMM approach denoted by Blundell and Bond (1998) is employed.

Dynamic specification allows total factor productivity to depend on its own past realizations, reflecting adjustment dynamics in firms' productivity processes. Moreover, the System GMM approach gives parameters in first difference and in level, utilizing instruments which are internal coming from one period lagged of observations. This framework gives an improvement on effectiveness and solves the weak instrument problems that may arise in difference GMM, particularly in panels with persistent series. To correct for the downward bias in standard errors associated with two-step GMM estimation, the finite-sample correction proposed by Windmeijer (2005) is applied. Following Roodman (2009), the alternative instrument structures are considered, including specifications with and without collapsed instrument matrices, in order to limit instrument proliferation and avoid overfitting.

The dynamic model is given as:

$$TFP_{ijt} = B_0 + \theta TFP_{ijt-1} + \alpha\, RD_{ijt} + \mathrm{B}'X_{ijt} + \gamma_i + \delta_j + \lambda_t + \varepsilon_{ijt}, \tag{3.8}$$

where:

- $\boldsymbol{TFP_{ijt}}$ represents the total factor productivity of firm i operating in industry j at time t,
- $\boldsymbol{TFP_{ijt-1}}$ represents the lagged of dependent variable TFP for the firm i in sector j at time t,

- $\boldsymbol{RD_{ijt}}$ represents the R&D expenditures of firms with the coefficient of $\boldsymbol{\alpha}$,
- $\boldsymbol{X_{ijt}}$ represents the control variables with the matching coefficient vector $\mathbf{B}'$,
- $\boldsymbol{\gamma_i}$ represents firm-specific fixed effects,
- $\boldsymbol{\delta_j}$ represents industry-specific fixed effects,
- $\boldsymbol{\lambda_t}$ represents time-specific fixed effects,
- $\boldsymbol{\varepsilon_{ijt}}$ represents the error term for the firm i in sector j at time t.

Specification tests proposed by Arellano and Bond (1991) are used to assess the validity of the dynamic model. In particular, the absence of second-order serial correlation in first-differenced errors is evaluated using the AR test. Failure to reject the null hypothesis of no AR(2) correlation supports the validity of the moment conditions. In addition, the Hansen test of overidentifying restrictions is employed to assess the overall validity of the instrument set. All explanatory and control variables are expressed in natural logarithms. Therefore, the meausred parameters can be described utilizing elasticity, showing a percentage altering in total factor productivity link with one percentage altering in the independent and control variables (Wooldridge, 2019; Gujarati and Porter, 2009; Stock and Watson, 2020).

4. RESULTS AND DISCUSSION

This part shows the main empirical findings of the analysis and gives a structured interpretation of results within both an econometric and a theoretical framework. The analysis proceeds in three interconnected stages. First, static panel data models are estimated to establish baseline evidence on connection with firms' R&D expenditures and TFP by controlling for unobserved firm, sector and time heterogeneity. Second, the dynamic panel data models are employed to account for productivity persistence and potential endogeneity, using alternative estimation strategies, including System GMM, in order to obtain consistent and economically meaningful parameter estimates. Finally, the discussion section situates the empirical findings within the existing firm-level innovation and productivity literature by systematically comparing the results with prior empirical studies reviewed in the literature section, highlighting the areas of consistency, convergence, and contribution. This integrated structure allows the chapter not only to present consistent econometric finding on productivity impacts of R&D investments, but also to interpret these findings in relation to established theoretical and empirical insights, thereby strengthening the study's overall contribution to the literature on innovation-driven productivity dynamics.

4.1 Static Panel Data Models Results

Hausman test finding for the TFP estimates obtained utilizing the LP-ACF method are given under the Table 4.1. The specification rejects the null hypothesis. This indicates that the estimating through random effects is not consistent and so estimating through fixed effects is consistent to estimate the model.

Table 4.1 : Hausman Test Results for TFP Estimation by LP-ACF Method.

Test Statistic	Degrees of Freedom	p-value
477.17	15	0.0000

Similarly, Table 4.2 shows the specification of the Hausman test of TFP estimates obtained using the OP-ACF method. The null hypothesis is again rejected, implying that the estimator of fixed effects is preferrable over the random effects for this specification as well.

Table 4.2 : Hausman Test Results for TFP Estimation by OP-ACF Method.

Test Statistic	Degrees of Freedom	p-value
361.01	15	0.0000

The baseline specification includes only the main variable of interest, namely firms' R&D expenditures. The corresponding results are represented in Table 4.3. No control metrics or fixed effects are included in this specification; therefore, the estimates reflect the unconditional connection with R&D expenditures and TFP. The results are presented for TFP measured utilizing the LP method with ACF correction (LP-ACF) and OP method with ACF correction (OP-ACF).

Through the findings in Table 4.3, one percentage rise in R&D expenditures is linked with a rise of almost 0.101 percent increase in TFP measured by the LP-ACF method and 0.086 percent rise in TFP estimated by the OP-ACF approach. These two coefficients are statistically significant at the 1 percent. Although the findings show a positive link with R&D expenditures and productivity, this simple OLS specification provides only limited and potentially biased evidence. Since no control variables or fixed effects are controlled for, the estimates are likely to suffer from omitted variable bias and unobserved firm-level heterogeneity.

Table 4.3 : Regression Results.

	LP-ACF	OP-ACF
R&D	0.101*** (0.001)	0.086*** (0.001)
Observation number	72,893	72,893
R^2	0.0758	0.0547

Standard errors in parantheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

To address the limitations of the baseline specification, the analysis is extended by incorporating year fixed effects. Including time fixed effects allows the model to control for common macroeconomic shocks, policy changes, and economy-wide trends that may simultaneously affect firms' R&D decisions and productivity levels. By accounting for these time-specific factors, the estimated relationship between R&D expenditures and TFP is less likely to be driven by aggregate fluctuations and provides a more informative benchmark relative to the unconditional OLS results.

Year fixed effects are included in the high-dimensional fixed effects OLS estimation in order to control for time-specific shocks that may affect all firms simultaneously. This specification removes part of the bias arising from unobserved time-related factors and purifies the estimates from common year effects. The corresponding results are reported in Table 4.4.

Through the estimates, one percentage rise in R&D expenditures is linked with an rise of approximately 0.098 percentage in TFP estimated by LP-ACF method and 0.083 percent in TFP estimated by the OP-ACF method. Two coefficients are statistically significant.

Although the integration of year-fixed effects improves this estimation relative to the baseline OLS model, this specification still provides limited and potentially biased evidence. Other firm-level characteristics that affect productivity are not yet controlled for, and unobserved heterogeneity across firms and industries remains. Since firm fixed effects are not included, the estimates reported in Table 4.4 may still suffer from omitted variable bias at the firm level.

Table 4.4 : Year Fixed Effects Results.

	LP-ACF	OP-ACF
R&D	0.098*** (0.001)	0.083*** (0.001)
Year Fixed Effect	Yes	Yes
Observation number	72,893	72,893
R^2	0.0944	0.0769
Adjusted R^2	0.0942	0.0767
Root MSE	0.9349	0.9491

Standard errors in parantheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Firm and year fixed effects are integrated in the OLS estimation so as to control unobserved heterogeneity across time and firms. This specification accounts for time-specific shocks as well as time-invariant firm characteristics. Also, standard errors are clustered at the firm level to allow for within-firm correlation over time and heteroskedasticity.

The results are shown in Table 4.5. According to the estimates, one percentage rise in R&D expenditures is linked with a rise of approximately 0.024 percent in TFP estimated by the LP-ACF method and 0.022 percent in TFP estimated by the OP-ACF method. Two coefficients are statistically significant at the 1 percent level.

Although controlling for year and firm fixed effects substantially improves the specification relative to the previous models, this specification may still suffer from remaining sources of bias. In particular, sector-specific shocks and structural differences across industries are not yet controlled for. Since sector fixed effects are not integrated, the model reported in Table 4.5 may still be affected by unobserved industry-level heterogeneity.

Table 4.5 : Year and Firm Fixed Effects Results.

	LP-ACF	OP-ACF
R&D	0.024*** (0.003)	0.022*** (0.003)
Year Fixed Effect	Yes	Yes
Firm Fixed Effect	Yes	Yes
Observation number	60,837	60,837
R^2	0.6857	0.6897
Adjusted R^2	0.6089	0.6138
Root MSE	0.5867	0.5905

Standard errors in parantheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In the following specification, year, firm, and industry fixed effects are included in the estimation controlling heterogeneity across time, firms, and sectors. This specification accounts for time-specific shocks, time-invariant firm characteristics, and structural differences among industries.

Standard errors are clustered at the firm level to allow for within-firm correlation over time and heteroskedasticity. The findings are given under the Table 4.6.

Through to the findings reported in Table 4.6, a percent rise in R&D expenditures is linked with a rise almost 0.024 percent in TFP estimated by the LP-ACF method and 0.022 percent in TFP estimated by OP-ACF approach. Both coefficients are statistically significant at the 1 percent level.

Although the integration of year, firm, and industry fixed effects substantially improves the specification relative to the baseline models, the findings should still be read with caution. Even multi-level fixed effects model may remain subject to omitted variable bias arising from time-varying observed factors that are not gathered through fixed-effects structure.

Table 4.6 : Results with Year, Firm and Industry Fixed Effects.

	LP-ACF	OP-ACF
R&D	0.024*** (0.003)	0.022*** (0.003)
Year Fixed Effect	Yes	Yes
Firm Fixed Effect	Yes	Yes
Industry Fixed Effect	Yes	Yes
Observation number	60,837	60,837
R^2	0.6860	0.6899
Adjusted R^2	0.6091	0.6140
Root MSE	0.5866	0.5904

Standard errors in parantheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In next step, control parameterd are added to the model together with the main variable of interest, R&D expenditures, so as to reduce the omitted variable bias. Full specification includes total assets, net sales, net profit, total foreign assets, and total creditors’ equity as control variables. All variables are normalized by the Producer Price Index (PPI) and expressed in natural logarithms. In this specification, fixed effects are not integrated so as to isolate role of observable firm characteristics.

The model findings are given in Table 4.7. The findings show that a percentage rise in R&D expenditures is linked with a rise of almost 0.038 percentage in TFP estimated by LP-ACF method and 0.041 percent in TFP estimated by the OP-ACF method after controlling for covariates. Both estimates are statistically significant at the 1 percent level. All control variables are also statistically significant at the 1 percent level.

Total assets have a negative impact on productivity: a percentage rise in total assets reduces TFP by 0.136 percent under the LP-ACF method and by 0.186 percent under the OP-ACF method. A similar but weaker negative effect is observed for net sales, where one percent increase reduces TFP by 0.015 percent (LP-ACF) and 0.014 percent (OP-ACF).

In contrast, net profit has a positive and economically strong effect on productivity. One percent increase in net profit raises TFP by 0.268 percent under LP-ACF and by 0.270 percent under OP-ACF. Both total foreign assets and creditors' equity affect productivity negatively and significantly. A percentage rise in total foreign assets decreases TFP by 0.021 percent (LP-ACF) and 0.019 percent (OP-ACF), while one percent increase in creditors' equity reduces TFP by 0.053 percent and 0.055 percent, respectively.

Compared to the baseline specifications without control variables, the magnitude of the R&D coefficient declines once observable firm characteristics are included, indicating that part of the raw link with R&D and productivity is explained by firms' financial structure. Although the estimated effects are modest in magnitude, they suggest that R&D expenditures have a persistent and economically meaningful contribution to firm-level productivity even after controlling for firms' financial structure.

Overall, while the inclusion of control variables improves the explanatory power of the model, the absence of year, firm, and industry fixed effects implies that this specification may still suffer from bias due to unobserved heterogeneity. Therefore, these results should be interpreted with caution and mainly as a benchmark for the fixed effects specifications that follow.

Table 4.7 : With Control Variables.

	LP-ACF	OP-ACF
R&D	0.038*** (0.001)	0.041*** (0.001)
Total asset	-0.136*** (0.005)	-0.186*** (0.005)

Net sales	-0.015*** (0.003)	-0.014*** (0.004)
Net profit	0.268*** (0.002)	0.270*** (0.002)
Total foreign asset	-0.021*** (0.004)	-0.019*** (0.004)
Total equity of creditor	-0.053*** (0.003)	-0.055**** (0.003)
Observation number	51,536	51,536
R^2	0.3434	0.3264
Adjusted R^2	0.3433	0.3263
Root MSE	0.6804	0.7022

Standard errors in parantheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Since unobserved time-specific factors may affect productivity, year fixed effects are included in the specification that contains the main variable of interest and five control variables derived from firms' annual financial statements. The results are reported in Table 4.8. All coefficients are statistically significant, and their magnitudes are very similar to those reported in Table 4.7, where year fixed effects are not included.

According to the estimates, one percent increase in R&D expenditures is associated with an increase of approximately 0.037 percent in TFP measured by the LP-ACF method and 0.040 percent in TFP measured by the OP-ACF method. Both effects are statistically significant at the 1 percent level. All control variables are also significant at the 1 percent level.

The results indicate that total assets have a negative effect on productivity. One percent increase in total assets reduces TFP by 0.139 percent under the LP-ACF method and by 0.187 percent under the OP-ACF method. A similar but weaker negative effect is observed for net sales: one percent increase in net sales decreases TFP by 0.015 percent (LP-ACF) and 0.012 percent (OP-ACF).

In contrast, net profit has a positive and statistically significant effect on productivity. One percent increase in net profit raises firms' TFP by approximately 0.268 percent under both productivity measures. Total foreign assets and creditors' equity, however, affect productivity negatively and significantly. One percent increase in total foreign assets decreases TFP by 0.023 percent (LP-ACF) and 0.022 percent (OP-ACF), while one percent increase in creditors' equity reduces TFP by 0.050 percent and 0.051 percent, respectively.

The similarity of the coefficient estimates in Tables 4.7 and 4.8 suggests that time-specific shocks do not substantially drive the estimated relationship between R&D expenditures and productivity. Although the estimated effects are modest in magnitude, they indicate that R&D expenditures contribute persistently to firm-level productivity.

Overall, while the inclusion of year fixed effects improves the specification relative to the models without time controls, this model may still suffer from bias due to the exclusion of firm and industry fixed effects.

Table 4.8 : Year Fixed Effect Result with Control Variables.

	LP-ACF	OP-ACF
R&D	0.037*** (0.001)	0.040*** (0.001)
Total asset	-0.139*** (0.005)	-0.187*** (0.005)
Net sales	-0.015*** (0.003)	-0.012*** (0.004)
Net profit	0.268*** (0.002)	0.268*** (0.002)
Total foreign asset	-0.023*** (0.004)	-0.022*** (0.004)
Total equity of creditor	-0.050*** (0.003)	-0.051*** (0.003)
Year Fixed Effect	Yes	Yes
Observation number	51,536	51,536
R^2	0.3585	0.3423
Adjusted R^2	0.3583	0.3421
Root MSE	0.6725	0.6939

Standard errors in parantheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

In the next specification, year and firm fixed effects are included in the estimation model together with the main variable of interest and five control variables from firms' annual financial statements. Standard errors are clustered at the firm level. The results are reported in Table 4.9.

According to the estimates, one percent increase in R&D expenditures increases TFP measured by both the LP-ACF and OP-ACF methods by approximately 0.004 percent. This effect is statistically significant only at the 10 percent level.

The results indicate that total assets have a negative and statistically significant effect on productivity at the 1 percent level. One percent increase in total assets reduces TFP by 0.101 percent under the LP-ACF method and by 0.134 percent under the OP-ACF method. In contrast, the effect of net sales is not statistically significant.

Net profit has a positive and highly significant effect on productivity. One percent increase in net profit raises firms' TFP by approximately 0.197 percent under both productivity measures. Finally, the effects of total foreign assets and creditors' equity are statistically insignificant in this specification.

Table 4.9 : Year and Firm Fixed Effect Result with Control Variables.

	LP-ACF	OP-ACF
R&D	0.004* (0.002)	0.004* (0.002)
Total asset	-0.101*** (0.010)	-0.134*** (0.011)
Net sales	0.004 (0.007)	0.007 (0.007)
Net profit	0.197*** (0.004)	0.197*** (0.004)
Total foreign asset	0.008 (0.006)	0.004 (0.006)
Total equity of creditor	-0.000 (0.004)	-0.000 (0.004)
Year Fixed Effect	Yes	Yes
Firm Fixed Effect	Yes	Yes
Observation number	42,159	42,159
R^2	0.8375	0.8424
Adjusted R^2	0.7942	0.8003
Root MSE	0.3685	0.3732

Standard errors in parantheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

In the next specification, year, firm, and industry fixed effects are included in the estimation model together with the main variable of interest and five control variables from firms’ annual financial statements. Standard errors are again clustered at the firm level. The results are reported in Table 4.10.

According to the estimates, one percent increase in R&D expenditures increases TFP measured by both the LP-ACF and OP-ACF methods by approximately 0.004 percent. This effect is also only statistically significant at the 10 percent level.

The results indicate that total assets have a negative and statistically significant effect on productivity at the 1 percent level. One percent increase in total assets reduces TFP by 0.102 percent under the LP-ACF method and by 0.134 percent under the OP-ACF method. In contrast, the effect of net sales is not statistically significant.

Net profit has a positive and highly significant effect on productivity. One percent increase in net profit raises firms’ TFP by approximately 0.197 percent under both productivity measures. Finally, the effects of total foreign assets and creditors’ equity are statistically insignificant in this specification.

The sharp decline in the magnitude and significance of the R&D coefficient after controlling for year, firm, and industry fixed effects suggests that much of the raw correlation between R&D expenditures and productivity is driven by unobserved heterogeneity rather than a strong causal effect. Although the estimated effect of R&D remains positive, its small magnitude implies that increases in R&D expenditures alone may not generate large productivity gains without complementary factors such as firm capabilities or sector-specific conditions.

Table 4.10 : Year, Firm and Industry Fixed Effect Result with Control Variables.

	LP-ACF	OP-ACF
R&D	0.004* (0.002)	0.004* (0.002)
Total asset	-0.102*** (0.010)	-0.134*** (0.011)
Net sales	0.005 (0.007)	0.008 (0.007)
Net profit	0.197*** (0.004)	0.197*** (0.004)
Total foreign asset	0.008 (0.006)	0.004 (0.006)

Table 4.10 (Continued) : Year, Firm and Industry Fixed Effect Result with Control Variables.

	LP-ACF	OP-ACF
Total equity of creditor	-0.000 (0.004)	-0.000 (0.004)
Year Fixed Effect	Yes	Yes
Firm Fixed Effect	Yes	Yes
Industry Fixed Effect	Yes	Yes
Observation Number	42,158	42,158
R^2	0.8378	0.8427
Adjusted R^2	0.7945	0.8007
Root MSE	0.3682	0.3729

Standard errors in parantheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Despite the specifications reported above, three-dimensional fixed effects models may not fully resolve endogeneity concerns. To further mitigate this problem, a lagged specification is estimated. Specifically, one-period lagged values of R&D expenditures and one-period lagged values of the control variables are included in the three-dimensional fixed effects framework. The results are reported in Table 4.11, and standard errors are clustered at the firm level. Using lagged explanatory variables reduces the risk of reverse causality by ensuring that current productivity is explained by past firm behavior.

According to the estimates, one percent increase in the one-period lagged value of R&D expenditures increases TFP measured by the LP-ACF and OP-ACF methods by approximately 0.024 and 0.025 percent, respectively. Both effects are statistically significant at the 1 percent level. In addition, all one-period lagged control variables are statistically significant at the 1 percent level.

The results indicate that the one-period lagged value of total assets has a negative effect on productivity. One percent increase in lagged total assets reduces TFP by 0.096 percent under the LP-ACF method and by 0.139 percent under the OP-ACF method. A similar negative effect is observed for the one-period lagged value of net sales, which is also significant at the 1 percent level: one percent increase in lagged net sales decreases TFP by 0.026 percent (LP-ACF) and 0.029 percent (OP-ACF).

In contrast, the one-period lagged value of net profit has a positive and statistically significant effect on productivity. One percent increase in lagged net profit raises firms' TFP by 0.187 percent under the LP-ACF method and by 0.185 percent under the OP-ACF method. The effect of the one-period lagged value of total foreign assets is statistically insignificant under both productivity measures. Finally, one percent increase in the one-period lagged value of creditors' equity decreases TFP by approximately 0.034 percent under both methods.

Overall, although using lagged explanatory variables helps to alleviate reverse causality concerns, this specification may still suffer from bias, particularly due to the exclusion of firm fixed effects. Therefore, the results in Table 4.11 should be interpreted with caution. Compared to the contemporaneous specifications, the magnitude of the R&D coefficient changes once lagged values are used, suggesting that part of the immediate association reflects short-term simultaneity rather than purely dynamic effects.

Table 4.11 : Year and Industry Fixed Effect Result with Control Variables.

	LP-ACF	OP-ACF
R&D	0.024*** (0.002)	0.025*** (0.003)
Total asset	-0.096*** (0.011)	-0.139*** (0.011)
Net sales	0.026*** (0.007)	0.029*** (0.008)
Net profit	0.187*** (0.004)	0.185*** (0.004)
Total foreign asset	0.003 (0.009)	0.004 (0.009)
Total equity of creditor	-0.034*** (0.005)	-0.034*** (0.005)
Year Fixed Effect	Yes	Yes
Industry Fixed Effect	Yes	Yes
Observation Number	43,836	43,836
R^2	0.2792	0.2664

Table 4.11 (Continued) : Year and Industry Fixed Effect Result with Control Variables.

	LP-ACF	OP-ACF
Adjusted R^2	0.2786	0.2658
Root MSE	0.7391	0.7527

Standard errors in parantheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In the next model, year and industry fixed effects are included in the estimation model together with the variable of interest and five control variables obtained from firms' annual financial statements. In addition to the control variables, an interaction term between R&D expenditures and export intensity is included in the model. The interaction term between export intensity and R&D expenditures captures whether the productivity effect of R&D differs between high-exporting and low-exporting firms.

The estimated coefficient indicates how the marginal impact of R&D on TFP changes for firms with high export intensity relative to the others. The sign and significance of this coefficient determine whether exporting amplifies or weakens the productivity-enhancing the effect of R&D.

The results are reported in Table 4.12. Standard errors are again clustered at the firm level. The estimate of the interaction term is positive but statistically insignificant, suggesting that the effect of R&D expenditures may not depend on firms' export intensity. The estimated coefficients on R&D expenditures are 0.018 and 0.020. Both estimates are statistically significant at the 1 percent level.

The coefficient of total assets is negative and significant at the 1 percent level. Specifically, one percent increase in total assets decreases TFP estimated by the LP-ACF and OP-ACF methods by 0.136 and 0.183 percent, respectively. The effect of net sales on TFP is not statistically significant.

Total creditors' equity has a negative and significant effect on TFP at the 1 percent level. One percent increase in creditors' equity decreases TFP by 0.031 and 0.030 percent according to the LP-ACF and OP-ACF estimations, respectively. In contrast, net profit has a positive and significant effect on TFP at the 1 percent level.

One percent increase in net profit increases TFP by 0.256 percent under both productivity measures. The coefficient of total foreign assets is statistically insignificant.

Table 4.12 : Regression Result with an Interaction Term.

	LP-ACF	OP-ACF
R&D	0.018*** (0.002)	0.020*** (0.002)
Total asset	-0.136*** (0.009)	-0.183*** (0.009)
Net sales	-0.003 (0.007)	0.000 (0.007)
Net profit	0.256*** (0.004)	0.256*** (0.004)
Total foreign asset	-0.008 (0.008)	-0.006 (0.008)
Total equity of creditor	-0.031*** (0.004)	-0.030*** (0.004)
Interaction term: High Export*R&D	0.002 (0.002)	0.003 (0.002)
Year Fixed Effect	Yes	Yes
Industry Fixed Effect	Yes	Yes
Observation number	51,535	51,535
R^2	0.4102	0.4006
Adjusted R^2	0.4098	0.4002
Root MSE	0.6450	0.6626

Standard errors in parantheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

After conducting a comprehensive set of sensitivity checks with respect to alternative specifications of fixed effects and control variables, the results indicate that once firm fixed effects are incorporated into the estimation equation, the estimated coefficient on R&D expenditures remains statistically significant only at the 10 percent level.

4.2 Dynamic Panel Data Models Results

In this section, the estimation results based on dynamic panel data models are considered. These results are presented in a single table to facilitate comparison across different estimation approaches. The results are reported in Table 4.13. In this table, six different estimation methods are used to examine the impact of R&D expenditures on TFP estimated by the LP-ACF method, while controlling for financial variables derived from firms' balance sheets. In all models, standard errors are clustered at the firm level.

Table 4.13 shows that six different methods are implied in order to observe the impact of R&D expenditures on TFP of firms estimated by LP-ACF method by controlling financial parameters from the balance sheet of firms. Year, firm and industry fixed effects are included into the estimation. This provides an exclusion of the most part of biasness which is because of time, firm and sector heterogeneity. Therefore, the analysis is purified from the year, firm and industry effects by including time, firm and industry fixed effects. Moreover, standard errors are clustered in firm-level. When we investigate the results, OLS and fixed effect within regression results are important so as to compare the results whether the coefficient of one-year lagged value of TFP for the dynamic model is between the OLS and fixed effect within estimators. Then, since the coefficient obtained with the dynamic regressions with collapse and without collapse are 0.185 and 0.160, respectively, which are between the coefficient obtained from the OLS and fixed effect within regression, which are 0.557 and 0.119, respectively.

According to the dynamic regressions results without collapse, one percentage change in R&D expenditures increases TFP estimated by LP-ACF method by 0.016 at 1 percent significance level. While the dynamic regression result with collapse is examined, one percentage change in R&D expenditures increases TFP estimated by LP-ACF method by 0.017 at 1 percent significance level. The impact of the coefficient estimated with dynamic model with collapse is higher than the coefficient estimated with dynamic model without collapse.

Moreover, in order to compare the results of the control varibles, one percentage change in total assets decreases TFP estimated by LP-ACF method in the dynamic model without collapse and with collapse by 0.124 and 0.131 percent, respectively, at one percent significance level. Similar to the effects of total assets, one percentage change in net sales decreases TFP estimated by LP-ACF method in the dynamic model without collapse and with collapse by 0.056 and 0.044 percent, respectively, at one percent significance level. Through the results, the analysis shows that one percentage change in net profit increases TFP estimated by LP-ACF method in the dynamic model without collapse and with collapse by 0.229 and 0.237 percent, respectively, at one percent significance level. Similarly, one percentage change in total foreign assets increases TFP estimated by LP-ACF method in the dynamic model without collapse and with collapse by 0.023 and 0.020 percent, respectively. On the contrary, one percentage change in total equity of creditors decreases TFP estimated by LP-ACF method in the dynamic model without collapse and with collapse by 0.017 and 0.021 percent, respectively, at one percent significance level.

Moreover, for the dynamic models, the number of instruments is smaller than the number of groups or clusters. Also, for the specification test results for the dynamic models, AR(1) which is rejected and AR(2) which is not rejected show that order higher than one, there is no serial correlation by the test of no serial correlation. This also shows that model misspecification is not concern there with valid moment conditions. However, the Hansen test of overidentification restriction is significant, so the null hypothesis which is related with validity of instruments is rejected. Thus, this may be related with having some issues with instruments. That is, while there is no issue with the serial correlation tests, the results must be interpreted with caution due to the Hansen test.

Table 4.13 : Different Model Results. Dependent variable: TFP by LP-ACF Method.

	(1) OLS	(2) FE Within Regression	(3) FE	(4) FE with Interaction	(5) Dynamic	(6) Dynamic with collapse
L.TFP_lp_acf	0.557*** (0.011)	0.119*** (0.010)			0.178*** (0.015)	0.137*** (0.026)
R&D	0.018*** (0.001)	0.004** (0.002)	0.004* (0.002)	0.018*** (0.002)	0.016*** (0.028)	0.017*** (0.002)
Total asset	-0.102*** (0.007)	-0.072*** (0.010)	-0.102*** (0.010)	-0.136*** (0.009)	-0.124*** (0.008)	-0.131*** (0.009)
Net sales	-0.131*** (0.006)	-0.017* (0.009)	0.005 (0.007)	-0.003 (0.007)	-0.056*** (0.008)	-0.044*** (0.009)
Net profit	0.179*** (0.003)	0.182*** (0.003)	0.197*** (0.004)	0.256*** (0.004)	0.229*** (0.004)	0.237*** (0.005)
Total foreign asset	0.068*** (0.005)	0.024*** (0.006)	0.008 (0.006)	-0.008 (0.008)	0.023*** (0.007)	0.020** (0.007)
Total equity of creditor	-0.013*** (0.003)	0.000 (0.004)	-0.000 (0.004)	-0.031*** (0.004)	-0.017*** (0.004)	-0.021*** (0.004)
Interaction term: High Export*R&D				0.002 (0.002)		
Year Fixed Effect			Yes	Yes	Yes	Yes
Firm Fixed Effect			Yes		Yes	Yes
Industry Fixed Effect			Yes	Yes	Yes	Yes

Table 4.13 (Continued): Different Model Results. Dependent variable: TFP by LP-ACF Method.

	(1) OLS	(2) FE Within Regression	(3) FE	(4) FE with Interaction	(5) Dynamic	(6) Dynamic with collapse
Observation number	49,098	49,098	42,158	51,535	49,098	49,098
R^2	0.6192	0.3684	0.8378	0.4102		
Adjusted R^2			0.7945	0.4098		
Root MSE	0.50614		0.3682	0.6450		
AR(1) (p-value)					0.000	0.000
AR(2) (p-value)					0.462	0.805
Hansen test of overid. Restrictions (p-value)					0.000	0.000

Standard errors in parantheses and clustered in firm-level. * p < 0.1, ** p < 0.05, *** p < 0.01.

Finally, we report the estimation results based on the OP-ACF method. These results are presented in Table 4.14. As in Table 4.13, this table also includes estimation results for six different models. Again, standard errors are clustered at the firm level.

As observed in Table 4.14, the effect of R&D expenditures on TFP of firms estimated by OP-ACF method throuh six different methods by controlling financial parameters from the firms' balance sheet. Year, firm and industry fixed effects are included into the estimation. This provides an exclusion of the most part of biasness which is because of time, firm and sector heterogeneity. Therefore, the analysis is purified from the year effects, firm effects and industry effects by including time, firm and industry fixed effects. Moreover, standard errors are clustered in firm-level.

According to the results, OLS and fixed effect within regression results give an inference that the coefficient of one lagged value of TFP for the dynamic model is between the OLS and fixed effect within estimators. Then, since the coefficient obtained with the dynamic regressions with collapse and without collapse are 0.185 and 0.149, respectively, which are between the coefficient obtained from the OLS and fixed effect within regression, which are 0.547 and 0.132, respectively. According to the dynamic regressions results without collapse, one percentage change in R&D expenditures increases TFP estimated by OP-ACF method by 0.017 at 1 percent significance level. While the dynamic regression result with collapse is examined, one percentage change in R&D expenditures increases TFP estimated by OP-ACF method by 0.018 at 1 percent significance level. The impact of the coefficient estimated with dynamic model with collapse is higher than the coefficient estimated with dynamic model without collapse as in the case of estimating with LP-ACF.

Furthermore, so as to compare the impacts of the control varibles on TFP, one percentage change in total assets decreases TFP estimated by OP-ACF method in the dynamic model without collapse and with collapse by 0.163 and 0.172 percent, respectively, at one percent significance level. Similar to the effects of total assets, one percentage change in net sales decreases TFP estimated by OP-ACF method in the dynamic model without collapse and with collapse by 0.053 and 0.042 percent, respectively, at one percent significance level. Through the results, the analysis shows that one percentage change in net profit increases TFP estimated by OP-ACF method in the dynamic model without collapse and with collapse by 0.227 and 0.234 percent, respectively, at one percent significance level. Similarly, one percentage change in total foreign assets increases TFP estimated by OP-ACF method in the dynamic model without collapse and with collapse by 0.026 and 0.023 percent, respectively. On the contrary, one percentage change in total equity of creditors decreases TFP estimated by LP-ACF method in the dynamic model without collapse and with collapse by 0.016 and 0.020 percent, respectively, at one percent significance level.

Moreover, for the part of the dynamic model, the number of instruments is observed as smaller than the number of firm groups. Also, for the part of the specification test results for the dynamic models, AR(1) which is significant and AR(2) which is not significant show that order higher than one, there is no serial correlation by the test of no serial correlation. Then, it also shows that model misspecification is not a problem there with valid moment conditions. The Hansen test of overidentification restrictions is significant, so the null hypothesis which is related with validity of instruments is rejected. However, this may be related with having some issues with instruments.

Table 4.14 : Different Model Results. Dependent variable: TFP by OP-ACF Method.

	(1) OLS	(2) FE Within Regression	(3) FE	(4) FE with Interaction	(5) Dynamic	(6) Dynamic with collapse
L.TFP_op_acf	0.547*** (0.011)	0.132*** (0.010)			0.185*** (0.016)	0.149*** (0.026)
R&D	0.016*** (0.001)	0.004** (0.002)	0.004* (0.002)	0.020*** (0.002)	0.017*** (0.002)	0.018*** (0.002)
Total asset	-0.075*** (0.007)	-0.102*** (0.010)	-0.134*** (0.011)	-0.183*** (0.009)	-0.163*** (0.009)	-0.172*** (0.009)
Net sales	-0.127*** (0.006)	-0.020* (0.009)	0.008 (0.007)	0.000 (0.007)	-0.053*** (0.008)	-0.042*** (0.005)
Net profit	0.179*** (0.003)	0.183*** (0.003)	0.197*** (0.004)	0.256*** (0.004)	0.227*** (0.004)	0.234*** (0.009)
Total foreign asset	0.064*** (0.005)	0.024*** (0.006)	0.004 (0.006)	-0.006 (0.008)	0.026*** (0.007)	0.023** (0.007)
Total equity of creditor	-0.013*** (0.003)	0.000 (0.004)	-0.000 (0.004)	-0.030*** (0.004)	-0.016*** (0.004)	-0.020*** (0.004)
Interaction term: High Export*R&D				0.003 (0.002)		
Year Fixed Effect			Yes	Yes	Yes	Yes
Firm Fixed Effect			Yes		Yes	Yes
Industry Fixed Effect			Yes	Yes	Yes	Yes

Table 4.14 (Continued) : Different Model Results. Dependent variable: TFP by OP-ACF Method.

	(1) OLS	(2) FE Within Regression	(3) FE	(4) FE with Interaction	(5) Dynamic	(6) Dynamic with collapse
Observation number	49,098	49,098	42,158	51,535	49,098	49,098
R^2	0.6245	0.3755	0.8427	0.4006		
Adjusted R^2			0.8007	0.4002		
Root MSE	0.50258		0.3729	0.6626		
AR(1)					0.000	0.000
AR(2)					0.452	0.735
Hansen test of overid. Restrictions (p-value)					0.000	0.000

Standard errors in parantheses and clustered in firm-level. * p < 0.1, ** p < 0.05, *** p < 0.01.

4.3 Discussion

The empirical results of the analysis give consistent findings that firms' R&D expenditures are positively and statistically significantly related with TFP across a wide range of model specifications. Both static and dynamic estimations consistently indicate that R&D improves productivity at firm level. The magnitude of the estimated R&D effect declines as additional control variables and fixed effects are introduced, suggesting that part of the unconditional correlation between R&D and productivity reflects observable firm characteristics and unobserved heterogeneity rather than a purely causal relationship.

Our findings are coherent with the firm-level literature which gives a positive relation between R&D and productivity, including Hall and Mairesse (1995), Wakelin (2001), and Mamatzakis et al. (2023). In particular, the positive and significant R&D coefficients obtained from the dynamic specifications align with the findings of Dai et al. (2022), who emphasize the stress of measuring for endogeneity and persistence in productivity when measuring the effects of R&D capital. At the same time, the relatively reasonable magnitude of the estimated effects is in line with studies focusing on developing and emerging economies, where financial constraints, firm size distribution, and limited absorptive capacity may dampen the productivity impact of R&D investments (Ortega and Marin, 2011; Herzer, 2022).

From a methodological perspective, the analysis enriches to literature through measuring TFP using both Levinsohn–Petrin and Olley–Pakes approaches augmented with the ACF correction. As highlighted by Ackerberg et al. (2015) and Kané (2022), standard production function estimators may suffer from identification problems, and the ACF correction provides a more reliable framework for productivity measurement. The consistency of the results across LP-ACF and OP-ACF specifications strengthens the credibility of the empirical findings and suggests observed connection with R&D and productivity is not driven by a particular estimation method.

The utilization of dynamic panel data models further enhances analysis by addressing potential endogeneity arising from simultaneity, reverse causality, and persistence in productivity.

After the framework of Arellano and Bond (1991) and Blundell and Bond (1998), System GMM estimations yield plausible dynamic coefficients, with the lagged productivity term lying between the OLS and fixed effects estimators. Although the overidentifying restrictions test by Hansen is rejected in some specifications, instrument collapsing and lag restrictions are employed to mitigate instrument proliferation. As discussed by Roodman (2009), such outcomes are common in large samples and do not necessarily invalidate the results, however they indicate that the dynamic estimates should be interpreted with caution rather than strictly causal.

While R&D remains an important driver of firm-level productivity, its effectiveness appears to depend on firms' financial structure and broader institutional conditions. In the context of Türkiye, where firms may face financing constraints and structural heterogeneity across industries, innovation policies are likely to be more effective when combined with measures that strengthen firms' absorptive capacity, improve access to finance, and support long-term investment in knowledge and technology. Strengthening the design and targeting of R&D incentives may therefore enhance the contribution to productivity growth.

5. CONCLUSIONS AND RECOMMENDATIONS

This thesis examines the effect of firms' R&D expenses on TFP utilizing firm-level data for Türkiye over the period 2009–2023. So as to examine the research question, the static and dynamic panel data is implied to the firm-level data which includes firm level annual balance sheet data and annual industry and services statistics data where unique firm identification numbers and years are utilized to merge to these different datasets.

To address the research question, a comprehensive empirical framework is employed, combining static and dynamic panel data models that control for time, firm, and sector heterogeneity. TFP is measured utilizing both the Levinsohn–Petrin and Olley–Pakes approaches augmented through ACF correction, ensuring robustness to alternative productivity measurement techniques.

The empirical findings consistently show that R&D expenditures have a positive and statistically significant effect on productivity of firms across a wide range of model specifications. Baseline OLS estimations give a strong positive connection with R&D and productivity; however, this relationship weakens once control variables and fixed effects are introduced, suggesting that part of the unconditional correlation reflects observable firm characteristics and unobserved heterogeneity. A comprehensive set of sensitivity checks were conducted with respect to alternative specifications of fixed effects and control variables. The results indicate that, once firm fixed effects are incorporated into the estimation equation, the estimated coefficient on R&D expenditure remains statistically significant only at the 10 percent level. However, even after taking into account the effects of time and the sector, the firms' R&D expenditures continue to contribute to their productivity.

The dynamic panel data analysis further supports these findings. By employing System GMM estimators, the analysis accounts for persistence in productivity and potential endogeneity arising from simultaneity and reverse causality. The dynamic specifications yield economically plausible results, with the estimated coefficients of lagged productivity lying between those obtained from OLS and fixed effects estimations. Although some specifications indicate potential concerns regarding the instrument validity, the overall evidence gives a consistent positive connection through R&D expenditures and firm-level productivity.

The observations underline the stress of R&D as a driver of productivity growth among Turkish firms. However, the relatively reasonable magnitude of the estimated effects implies that R&D investments alone may not be sufficient to generate substantial productivity gains. Innovation perspectives are therefore possibly to be more effective when integrated by measures that strengthen firms' financial capacity. Targeted R&D incentives, combined with broader financial and institutional support mechanisms, may increase the productivity-enhancing impact of innovation activities.

Further research can be conducted by shaping the analysis through different sectors. It may be insightful to observe the differences between the sectors in terms of labour or capital intensity, and whether this has an effect on their R&D levels. Another suggestion is enhancing this analysis by including firm age and size. This would provide insight into whether the demographic specifications of firms affect their productivity levels. Rather than a firm-level analysis, it would be possible to conduct a macro evidence so as to analyze the productivity effect on a country's growth for the economy. This could also be investigated at a country level. Moreover, the part for the dynamic models that gives specification test results, it is suggested that the dynamic model may be developed in order to obtain a valid instrument test result through Hansen test in further research.

In conclusion, the importance of R&D expenditures on firms' productivity is examined in this thesis. Thus, the results show that R&D expenditures of firms positively and significantly affect productivity of Turkish firms both for static and dynamic firm level panel data analysis. Overall, this thesis provides empirical evidence that R&D expenditures play a significant and positive role in enhancing firm-level productivity in Türkiye. By combining advanced productivity estimation techniques with static and dynamic panel data methods, the study contributes to the literature on innovation and productivity using unique firm-level data and offers relevant implications for both policy design and future research.

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APPENDICES

This appendix parts include the correlations for productivity estimation and the parameterd utilized in the regression models.

Table A.1 gives the correlation table for productivity estimations.

Table A.2 gives the correlation table for the variables utilized for the regression models.

Table A.1 : Correlation Matrix for Productivity Estimation.

	TFP by OLS	TFP by FE	TFP by OP-ACF	TFP by OP	TFP by LP-ACF	TFP by LP	Labor Productivity
TFP by OLS	1.0000						
TFP by FE	0.9979	1.0000					
TFP by OP-ACF	0.8958	0.8674	1.0000				
TFP by OP	0.8946	0.8678	0.9961	1.0000			
TFP by LP-ACF	0.8975	0.8697	0.9930	0.9961	1.0000		
TFP by LP	0.8677	0.8450	0.9580	0.9793	0.9768	1.0000	
Labor Productivity	0.8183	0.7953	0.8776	0.9026	0.9281	0.9444	1.0000

Table A.2 : Correlation Matrix for Variables Used in the Model.

	TFP by LP-ACF	TFP by OP-ACF	Natural logarithm of R&D Expenditures	Natural logarithm of total assets	Natural logarithm of net sales	Natural logarithm of net profit	Natural logarithm of total foreign assets	Natural logarithm of creditors' equity
TFP by LP-ACF	1.0000							
TFP by OP-ACF	0.9892	1.0000						
Natural logarithm of R&D Expenditures	0.2915	0.2416	1.0000					
Natural logarithm of total assets	0.1161	-0.0067	0.4453	1.0000				
Natural logarithm of net sales	0.0996	-0.0136	0.4137	0.9255	1.0000			
Natural logarithm of net profit	0.4192	0.3176	0.5063	0.8047	0.7562	1.0000		
Natural logarithm of total foreign assets	0.0233	-0.0888	0.3611	0.9204	0.8743	0.6909	1.0000	
Natural logarithm of creditors' equity	-0.0281	-0.1292	0.2907	0.8266	0.8217	0.6905	0.9038	1.0000

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- **M.A.** **:** 2026, Istanbul Technical University, Economics, *Dissertation Stage*