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FOREIGN DIRECT INVESTMENT AND PRODUCTIVITY NEXUS IN TURKIYE'S MANUFACTURING INDUSTRY: A SECTORAL ANALYSIS (2009-2022)

Abdullah Bahadır ŞAŞMAZ[1]

Abstract
This study examines the relationship between foreign direct investment (FDI) inflows and productivity in Türkiye's manufacturing industry, focusing on 14 sub-sectors from 2009 to 2022. The analysis aims to evaluate the impact of both current and lagged FDI on productivity dynamics using standard panel data, co-integration analysis, Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and a Panel Autoregressive Distributed Lag (ARDL) model to estimate short and long-term effects. In the short term, standard panel models show productivity has a positive relationship with current FDI inflows and per capita personnel costs, and a negative relationship with the turnover index. However, no significant relationship was found with lagged FDI. The Panel ARDL model confirms these dynamics, identifying a statistically significant positive FDI impact in seven of the fourteen sectors, highlighting sectoral heterogeneity. Long-term analysis reveals a different dynamic. While no direct relationship exists between current FDI and productivity, lagged FDI inflows positively impact sectoral performance. This finding is robustly confirmed by the Panel ARDL model, which indicates a stable long-run relationship via a significant error correction term. Furthermore, per capita personnel costs and the turnover index show positive long-term effects. These findings emphasize the need for strategic, sector-specific policies. The varied impact of FDI suggests a need to distinguish between high-absorption sectors that readily benefit and those requiring foundational capacity building to maximize FDI's contribution to sustainable productivity growth.
Keywords: Foreign direct investment, Productivity, Panel data analysis, Co-integration analysis, Autoregressive distributed lag analysis.
JEL Codes: E22, E23, O47

TÜRKİYE İMALAT SANAYİSİNDE DOĞRUDAN YABANCI YATIRIM VE VERİMLİLİK İLİŞKİSİ: SEKTÖREL BİR ANALİZ (2009-2022)

Öz
Bu çalışma, 2009-2022 döneminde Türkiye imalat sanayisindeki doğrudan yabancı yatırım (DYY) girişleri ile verimlilik arasındaki ilişkiyi 14 alt sektör özelinde incelemektedir. Analiz, kısa ve uzun dönemli etkileri tahmin etmek amacıyla standart panel veri, eşbütünleşme analizi, Modifiye Edilmiş Sıradan En Küçük Kareler Yöntemi (FMOLS), Dinamik Sıradan En Küçük Kareler Yöntemi (DOLS) ve bir panel Gecikmesi Dağıtılmış Otoresresif (ARDL) model kullanarak mevcut ve gecikmeli DYY'nin verimlilik dinamikleri üzerindeki etkisini değerlendirmeyi amaçlamaktadır. Kısa dönemde, standart panel modelleri verimliliğin mevcut DYY girişleri ve kişi başı personel maliyetleri ile pozitif, ciro endeksi ile ise negatif bir ilişkiye sahip olduğunu göstermektedir. Bununla birlikte, gecikmeli DYY ile anlamlı bir ilişki bulunamamıştır. Panel ARDL modeli bu dinamikleri teyit ederek, on dört sektörün yedisinde istatistiksel olarak anlamlı pozitif bir DYY etkisi tespit etmiş ve sektörel heterojenliğin altını çizmiştir. Uzun dönem analizi farklı bir dinamik ortaya koymaktadır. Mevcut DYY ile verimlilik arasında doğrudan bir ilişki bulunmazken, gecikmeli DYY girişleri sektörel performansı pozitif etkilemektedir. Bu bulgu, anlamlı bir hata düzeltme terimi aracılığıyla istikrarlı bir uzun dönem ilişkisine işaret eden Panel ARDL modeli tarafından da güçlü bir şekilde doğrulanmaktadır. Ayrıca, kişi başı personel maliyetleri ve ciro endeksi de uzun dönemde pozitif etkiler göstermektedir. Bu bulgular, stratejik ve sektöre özgü politikalara duyulan ihtiyacı vurgulamaktadır. DYY'nin çeşitli etkileri, DYY'nin sürdürülebilir verimlilik artışına katkısını en üst düzeye çıkarmak için yatırımlardan kolayca faydalanan yüksek hazmetme kapasiteli sektörler ile temel kapasite geliştirmeye ihtiyaç duyan sektörler arasında bir ayrım yapılması gerektiğini ortaya koymaktadır.
Anahtar Kelimeler: Doğrudan yabancı yatırım, Verimlilik, Panel veri analizi, Eşbütünleşme analizi, Gecikmesi dağıtılmış otoregresif model analizi.
JEL Kodları: E22, E23, O47.

[1] Dr., Kartal Municipality, a.bahadirsasmaz@gmail.com, ORCID: 0000-0001-5059-4554
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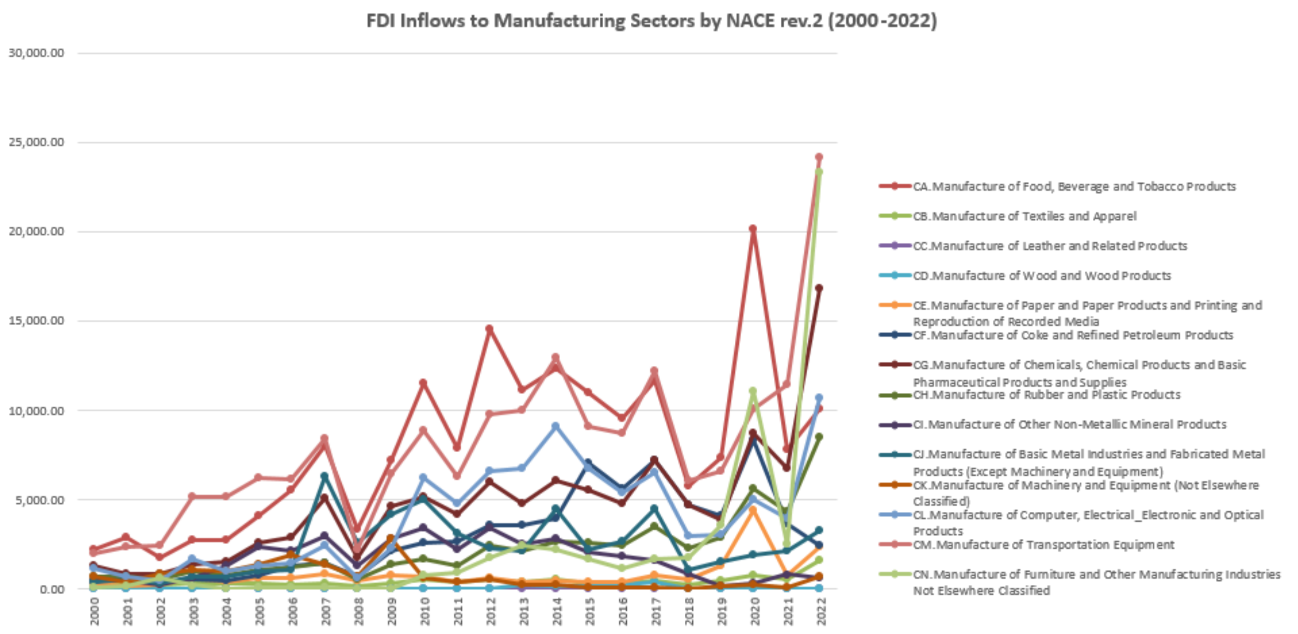
Introduction

The role of foreign direct investment (FDI) in driving economic development and productivity growth has long been a topic of scholarly and policy interest. FDI is widely regarded as a critical channel for transferring advanced technologies, managerial expertise, and global market access, thereby fostering productivity improvements across recipient economies (Qasim & Su, 2022, p. 4). However, the extent of these benefits is contingent on various factors, including the absorptive capacities of sectors (Chudnovsky *et al*., 2008, p. 664-666), the dynamism of local markets, and the interplay between foreign capital and domestic structures (Phelps, 2008, p. 468-469).

Figure 1: *FDI Inflows to Manufacturing Sectors (2000-2022)*



Source: Central Bank of the Republic of Türkiye (TCMB) (2024)

The Turkish manufacturing industry provides a compelling case for examining this relationship. As illustrated in Figure 1, which highlights FDI inflows across Türkiye's manufacturing sub-sectors from 2000 to 2022, there has been notable growth in key industries such as transportation equipment (CM), food and beverages (CA), and chemical products (CG). These trends reflect the potential of FDI to enhance production capacities, foster technological advancements, and contribute to sectoral development. For instance, the dramatic rise in FDI in high-value-added sectors like transportation equipment underlines its role in promoting technological progress and integration into global supply chains. However, the fluctuating patterns of FDI inflows in other sectors underscore the challenges of maintaining stable investments. This heterogeneity in investment flows leads to a critical policy question: To what extent do these FDI inflows contribute to productivity growth across different manufacturing sub-sectors, and are these effects sustained over time?

A significant body of research has explored this nexus in the Turkish context, with many studies providing valuable insights at the macroeconomic level, where long-run relationships have been established (e.g., Sofuoğlu and Kızılkaya, 2018; Okşak and Koyuncu, 2021), and at the firm-level, where spillovers are shown to depend on absorptive capacity (e.g., Benli, 2016; Fatima, 2016). However, two areas present an opportunity for a more granular analysis. First, while the importance of sectoral differences is widely acknowledged, the dynamic, time-varying effects of FDI are often not modelled across different manufacturing sub-sectors within a single, integrated framework. Second, a clear distinction between the immediate, short-run impacts and the long-run equilibrium relationship is often less emphasized. By addressing these points, this study aims to complement the existing literature by providing a nuanced understanding of FDI's role in shaping productivity within Türkiye's manufacturing sector, employing a methodological approach that captures both short-run and long-run dynamics.

To achieve this, the study examines the relationship between FDI and productivity in both the short and long term at the sectoral level for the period of 2009-2022. It investigates whether FDI acts as a catalyst for productivity gains across all manufacturing sub-sectors or whether its impact varies based on sector-specific characteristics. The research integrates key variables such as human capital, trade flows, and economic dynamism to capture the broader mechanisms driving productivity growth. Methodologically, this study employs the Panel Autoregressive Distributed Lag (ARDL) model, which is uniquely suited to simultaneously estimate both the heterogeneous short-run dynamics for each sector and the common long-run equilibrium relationship.

The interaction between FDI and sectoral identifiers is particularly significant, as it sheds light on the differential impacts of foreign investments in technology-intensive versus labor-intensive industries. Furthermore, the study considers the temporal dimension of FDI spillovers, distinguishing between immediate benefits and those materializing over time as firms adapt to and integrate foreign technologies. By employing econometric techniques to assess both short-term and long-term effects, this study aims to provide empirical evidence on the sustainability and effectiveness of FDI-driven productivity gains in Türkiye's manufacturing industry.

The findings of this study have implications for policymakers aiming to leverage FDI as a tool for sustainable development. By identifying the factors that enhance the effectiveness of FDI in boosting productivity, the research provides a foundation for designing targeted industrial and trade policies that align with the unique dynamics of individual sectors. A clear understanding of these dynamics will help policymakers develop strategies that maximize FDI's contribution to sectoral growth, ensuring that foreign investments translate into long-term industrial development rather than short-lived capital inflows. The remainder of this paper is organized as follows: Section 1 reviews the theoretical and empirical literature. Section 2 describes data and methodology. Section 3 presents and discusses the empirical results, and Section 4 concludes with policy implications.

1. Literature Review

1.1 Perspectives on FDI and Productivity

FDI is widely recognized as a key driver of productivity growth, particularly through its role in transferring advanced technology (Keller, 2010, p. 795) and managerial practices to host economies (Fu, 2012, p. 993-995). Borensztein *et al.* (1998, p. 117) emphasize that FDI has a more pronounced impact on productivity than domestic investment, provided the host country possesses a threshold level of human capital to effectively absorb these benefits. Similarly, Alfaro *et al.* (2004, p. 107-108) underline the importance of well-functioning local financial markets in enabling FDI to enhance productivity. Sectors with higher technological intensity, such as manufacturing, are particularly well-positioned to benefit from FDI, as Markusen and Venables (1999, p. 342-353) demonstrate that FDI can lead to industrialization and productivity gains through the development of backward and forward linkages.

Empirical studies often highlight the positive spillover effects of FDI, where foreign firms introduce competition, efficiency pressures, and new practices that benefit domestic firms. Caves (1974, p. 176-178) notes that such dynamics can lead to significant productivity improvements in host economies. Moreover, Javorcik (2004, p. 625) finds evidence of substantial productivity gains in Lithuanian manufacturing through backward linkages created by FDI. However, the magnitude of these benefits often depends on the absorptive capacity of domestic firms and the strength of linkages with foreign enterprises (Blomström & Kokko, 1998, p. 258-269). Furthermore, institutional quality, trade openness, and infrastructure are critical factors that influence the extent to which FDI contributes to productivity, as Rodrik (2008, p. 99-152) argues.

Despite these potential benefits, FDI does not uniformly enhance productivity, and its impacts can sometimes be negative. One significant critique is that FDI may crowd out domestic firms, particularly in sectors with limited competition or where foreign firms dominate the market. Aitken and Harrison (1999, p. 606-616) show that in Venezuelan manufacturing, FDI led to limited productivity spillovers, partly due to weak absorptive capacities and competitive pressures that displaced domestic firms. This crowding-out effect occurs when foreign firms, leveraging their superior resources and global networks, outcompete local firms, forcing them to scale down or exit the market. Such dynamics can reduce overall productivity if displaced local firms were more efficient in their resource utilization.

Resource misallocation is another potential drawback, as foreign firms may receive preferential treatment from policymakers or financial institutions, such as tax incentives or easier access to capital, diverting resources away from domestic firms (Rodrik, 2008, p. 99-152). This distortion may hinder productivity growth by limiting the expansion and innovation potential of highly efficient local firms. Moreover, in some cases, foreign firms may retain critical knowledge or advanced technologies within their parent companies, offering limited benefits to host economies. Blomström and Kokko (1998, p. 269-272) and Gorg and Greenaway (2004, p. 181-190) highlight that weak linkages between foreign and domestic firms or inadequate absorptive capacities of local enterprises exacerbate this issue.

FDI can also create dependency on foreign capital and technologies, discouraging local innovation and entrepreneurship. Gallagher and Zarsky (2007, p. 13-192) argue that such reliance may undermine the development of indigenous capabilities, thereby restricting sustainable productivity growth in the long term. Negative spillovers may also arise when foreign firms poach skilled labor from domestic enterprises, driving up wage levels and production costs. Driffield and Taylor (2000, p. 90-100) illustrate that this competition for resources can adversely affect productivity, especially in labor-intensive sectors.

While FDI has the potential to significantly enhance productivity through technology transfer, spillover effects, and industrial linkages, its impact is contingent on host-country conditions and sectoral characteristics. Crucially, the temporal dimension of these spillovers is a key theme in the literature, as the benefits of FDI—such as technology absorption and capacity building—are often not instantaneous but materialize over an extended period. Reflecting this dynamic, prominent studies by Li and Chen (2010), Ramasamy *et al.* (2017), and Bournakis and Tsionas (2022), among others, have utilized lagged FDI variables to capture the delayed nature of these effects on productivity. This necessitates an analytical approach that can distinguish between immediate and lagged impacts, which is a central focus of the present study.

1.2 Empirical Evidence from Türkiye

A number of empirical studies have investigated the FDI-productivity nexus within the Turkish context, offering valuable insights across macroeconomic, sectoral, and firm levels. This section reviews key contributions to situate the present study within the existing literature.

Arısoy (2012, p. 17-29) estimates FDI's contributions to total factor productivity (TFP) and economic growth in Türkiye for the period 1960–2005. The study emphasizes technology spillovers and physical capital accumulation as critical channels through which FDI influences TFP and growth.

Filiz (2014, p. 23-27) extends the analysis to BRIC countries and Türkiye, identifying a negative relationship between FDI and TFP. The study highlights potential disparities in the absorptive capacities of different countries and their ability to benefit from FDI inflows.

Benli (2016, p. 177-196) focuses on firm-level absorptive capacity and its role in capturing productivity spillovers from FDI for the period of 2003-2012. Through conditional quantile regressions, the study reveals that medium- and high-productivity firms benefit more from FDI spillovers, highlighting the heterogeneity in firms' productivity dynamics.

Fatima (2016, p. 291-324) examines horizontal and vertical linkages of FDI-induced spillovers using firm-level data for the period of 2003-2010. The study finds that horizontal linkages negatively impact productivity, while vertical linkages have a positive effect, highlighting the importance of supplier-buyer relationships between local and multinational firms.

Kalemli-Ozcan *et al.* (2016, p. 1-34) analyze the impact of FDI on productivity and discuss how Türkiye can enhance FDI inflows by improving institutional quality and reducing exchange rate volatility. Their findings underscore the role of knowledge spillovers and the delayed productivity gains experienced by Turkish firms receiving FDI.

Sofuoğlu and Kızılkaya (2018, p. 505-518) investigate the long-term relationship between FDI and labor productivity in Türkiye from 1971 to 2015. Using Johansen cointegration and DOLS techniques, they find a positive and significant impact of FDI on labor productivity, with bidirectional causality reinforcing the feedback loop between FDI and productivity growth.

Karahan and Colak (2021, p. 26-34) explore the spillover effects of FDI in Eastern European countries, revealing the prevalence of positive backward spillovers while horizontal and forward spillovers are absent. Their sectoral analysis suggests similar effects across manufacturing and services.

Okşak and Koyuncu (2021, p. 253-277) explore the long-run asymmetric relationship between FDI and productivity in Türkiye using a Nonlinear ARDL (NARDL) approach with macro-level data. They provide evidence of a nonlinear association between FDI inflows and labor productivity, emphasizing that increases and decreases in FDI have asymmetric effects. Their study is unique in its macro-level focus and its use of distinct productivity indicators to address asymmetry.

Sözüer (2023, p. 12-21) examines labor productivity in foreign-capitalized and domestic manufacturing firms in Türkiye. Using data from 2011-2019 period of 27 industries, the study identifies FDI's intra-industry spillover effects and convergence in productivity levels between foreign and domestic firms. The findings highlight FDI's contribution to labor productivity growth and emphasize the importance of policy measures to optimize these spillovers.

Taken together, the empirical literature on Türkiye paints a complex and multifaceted picture. While most studies confirm that FDI is a significant factor in productivity, the direction and magnitude of its effect appear highly dependent on whether the analysis is conducted at the macro, firm, or sectoral level; which type of spillovers are considered, such as horizontal or vertical; and the absorptive capacity of domestic firms. A recurring theme is the importance of firm-level and sectoral heterogeneity, which broad macroeconomic studies may not fully capture.

The valuable insights from the existing literature have robustly documented the FDI-productivity link in Türkiye, largely from a macroeconomic or firm-level standpoint. This study aims to complement this body of work by focusing on two specific areas: the heterogeneity of effects at the sectoral level, and the integrated modelling of short-term dynamics alongside the long-run equilibrium relationship. By doing so, it provides a different and more nuanced perspective on the spillover process.

This study contributes to the literature by providing a comprehensive sectoral analysis that first establishes baseline short- and long-run relationships before confirming and extending these findings with a dynamic panel model. It integrates the effects of current and lagged FDI inflows, examining their impact on productivity dynamics while considering sector-specific characteristics. The study bridges short-term and long-term perspectives using an initial analysis based on random-effects and panel cointegration methods, which are then complemented by a more advanced Panel ARDL estimation to ensure robust and policy-relevant findings.

2. Methodology and Dataset

2.1 Theoretical Background

The theoretical foundation of this analysis lies in endogenous growth theory, particularly the models of Romer (1990, p. 71-102) and Lucas (1988, p. 3-42), which emphasize productivity as a function of capital accumulation, human capital, and technological innovation. This study builds on these frameworks by examining the sectoral heterogeneity of FDI spillovers and their long-term implications for productivity growth. While traditional growth models highlight the role of capital and labor in productivity, sectoral differences in absorptive capacity, technological intensity, and market structure necessitate a more nuanced approach to understanding FDI's impact. This research contributes to the literature by explicitly incorporating sector-specific factors into the analysis.

The Cobb-Douglas type production function of a representative firm can be expressed as:

$$Y = AK^{\alpha}L^{1-\alpha} \tag{1}$$

where:

Y: Output (proxied by productivity, Value Added at Factor Cost / Number of Employees)

K: Capital (represented by foreign/fixed capital, FDI and purchase of commercial goods as operational capital)

L: Labor (captured through Personnel Cost Per Person)

A: Total Factor Productivity (TFP), which incorporates technological progress, spillovers, and efficiencies arising from FDI.

FDI plays a crucial role in enhancing productivity by acting as a conduit for technology transfer, skill acquisition, and industrial upgrading. However, the extent of these benefits varies across sectors, depending on domestic firms' absorptive capacity, the nature of backward and forward linkages, and the intensity of competition. This study integrates these elements into the theoretical framework to better explain sector-specific FDI dynamics. FDI affects A by transferring technology, introducing managerial know-how, and fostering competition. Current and lagged FDI variables in the models proxy for these effects.

Dynamic Productivity Spillovers: Productivity effects of FDI often exhibit time-lagged dynamics. These dynamics can be captured through an augmented production function:

$$Y_{it} = A_{it}K_{it}^{\alpha}L_{it}^{1-\alpha} \tag{2}$$

where A_{it} evolves over time as:

$$A_{it} = A_0 e^{\lambda t} + \beta_1 \mathrm{FDI}_{it} + \beta_2 \mathrm{FDI}_{it-1} \tag{3}$$

FDI_{it} : Current inflows of FDI. It captures immediate spillover effects.

FDI_{it-1} : Lagged FDI, representing delayed spillover effects. This temporal lag is a critical feature, as the successful absorption of foreign technology and managerial practices is not instantaneous but requires a period of learning, adaptation, and integration by domestic firms (Blomström & Kokko, 1998). Furthermore, the development of robust backward and forward linkages, a key channel for spillovers (Markusen & Venables, 1999), is a process that unfolds over several periods. Therefore, including a lagged FDI term is essential to capture the full, cumulative impact of foreign investment on productivity.

Personnel Costs and Human Capital: Lucas (1988, p.17-27) highlighted that human capital enhances productivity via skills accumulation and knowledge diffusion. Personnel costs per person in the model proxy for investments in skilled labor:

$$H = e^{\phi E} \tag{4}$$

where:

H: Human capital

E: Educational or skill investments, proxied by personnel costs per person.

Higher H increases labor efficiency, which is reflected in A:

$$A = A_0 H \tag{5}$$

Human capital accumulation is particularly relevant in the FDI-productivity relationship, as firms in different sectors require different levels of expertise to effectively utilize foreign technologies. This underscores the importance of sectoral differences in explaining variations in FDI spillover effects.

Trade Flows and Productivity: Theoretical works such as Grossman and Helpman (1991, p. 1-384) highlight the role of trade in enhancing growth and therefore enhancing productivity through competition and technology spillovers. Küçük (2023, p. 548) also notes that technological progress and digitalization have a positive impact on trade flows. Export/import coverage ratio represents trade inflows and outflows.

$$A = A_0 \left(1 + \gamma \frac{\mathrm{EX}}{\mathrm{IM}}\right) \tag{6}$$

where γ reflects the sensitivity of TFP to trade flows.

Trade openness plays a complementary role in determining the productivity effects of FDI. In more open sectors, increased exposure to global markets can amplify FDI spillovers by facilitating knowledge diffusion and competitive pressures. In contrast, more protected industries may experience limited spillovers due to reduced foreign competition and weaker incentives for innovation.

Economic Dynamism and Turnover: Schumpeterian growth theory (Aghion & Howitt, 1992, p. 323-351) posits that market competition drives innovation and productivity. The turnover index in the model measures economic dynamism and market efficiency:

$$A = A_0(1 + \delta \mathrm{TO}) \tag{7}$$

where δ represents the elasticity of productivity to economic activity.

A dynamic economic environment fosters stronger FDI spillovers by encouraging firm entry, creative destruction, and efficiency improvements. However, the intensity of these effects varies by sector, depending on the competitive landscape and regulatory environment. This study accounts for these sectoral differences by incorporating market dynamism indicators.

Sectoral Heterogeneity and FDI: Markusen and Venables (1999, p. 335-356) emphasize that the impact of FDI is sector-specific, with greater benefits in technologically intensive sectors. Interaction terms between FDI and sectoral identifiers in the model capture this heterogeneity:

$$A_{it} = A_0 + \beta_1 FDI_{it} + \beta_2 FDI_{it} \cdot \mathrm{SectorID} \tag{8}$$

where SectorID (Code) identifies sector-specific absorptive capacities.

Sectoral heterogeneity is central to understanding the differential effects of FDI on productivity. High-tech industries, such as electronics and pharmaceuticals, typically benefit more from FDI due to their higher capacity for knowledge absorption and innovation. In contrast, low-tech industries may experience weaker spillovers, or even crowding-out effects, if foreign firms dominate domestic markets. This study explicitly models these sectoral variations to provide a more precise assessment of FDI's impact.

Input Utilization: The purchase of commercial goods in the model serves as a proxy for input utilization and working capital. From production theory, optimal input combinations maximize productivity:

$$Y = AK^{\alpha}(\mathrm{PCG})^{\beta}L^{1-\alpha-\beta} \tag{9}$$

where β measures the contribution of input utilization efficiency to output.

The efficiency of input utilization depends on sector-specific factors such as supply chain integration, labor intensity, and capital requirements. By incorporating these aspects into the theoretical framework, this study offers a more comprehensive understanding of FDI's role in driving sectoral productivity growth.

2.2 Dataset and Data Curation

The duration and categories of data available for each sub-sector are relatively limited. To address this, data from Turkstat (2024) covering the period 2009–2022 was utilized. Correspondingly, FDI data obtained from the Central Bank of the Republic of Türkiye (TCMB) were used to create a consistent panel for this timeframe. The dataset includes personnel costs, personnel numbers, turnover index, purchases of commercial goods, and trade data, all classified according to the NACE Rev. 2, 2-digit codes for the manufacturing sector. Within this classification, there are 23 sub-sectors under the Manufacturing main sector, ranging from codes 10 to 32. However, the TCMB's FDI data are aggregated under 14 sub-sector headings specific to manufacturing:

Table 1: *Aggregated Sectors by FDI Data and Corresponding NACE rev. 2 Codes*

Code	Aggregated Sector Names	NACE rev. 2 Codes for Aggregation
CA	Manufacture of Food, Beverage and Tobacco Products	10, 11, 12
CB	Manufacture of Textiles and Apparel	13, 14
CC	Manufacture of Leather and Related Products	15
CD	Manufacture of Wood and Wood Products	16
CE	Manufacture of Paper and Paper Products and Printing and Reproduction of Recorded Media	17, 18
CF	Manufacture of Coke and Refined Petroleum Products	19
CG	Manufacture of Chemicals, Chemical Products and Basic Pharmaceutical Products and Supplies	20, 21
CH	Manufacture of Rubber and Plastic Products	22
CI	Manufacture of Other Non-Metallic Mineral Products	23
CJ	Manufacture of Basic Metal Industries and Fabricated Metal Products (Except Machinery and Equipment)	24, 25
CK	Manufacture of Machinery and Equipment (Not Elsewhere Classified)	28
CL	Manufacture of Computer, Electrical_Electronic and Optical Products	26, 27
CM	Manufacture of Transportation Equipment	29, 30
CN	Manufacture of Furniture and Other Manufacturing Industries Not Elsewhere Classified	31, 32

Source: Calculated based on the data provided by TCMB (2024)

In line with this aggregation, other datasets were also adjusted accordingly. Personnel costs, personnel numbers, turnover index, purchases of commercial goods, and trade data were aggregated to match the structure of the FDI data. Additionally, value added at factor cost for the aggregated sectors was calculated using a weighted average method, with the weights based on the value-added contributions of the constituent NACE codes.

To ensure consistency, Producer Price Index (PPI) data were employed to deflate variables such as personnel costs, purchases of commercial goods, and value added at factor cost, which were originally recorded in Turkish lira. As the PPI data are monthly, their annual averages were calculated for this purpose. For trade data, although also denominated in Turkish lira, no deflation process was applied because the export-import coverage ratio was used instead. Finally, the natural logarithms of variables without inherent ratios, such as FDI, productivity, human capital and purchases of commercial goods, were taken to improve interpretability and reduce scale differences.

Table 2: *Variable Description*

Notation	Description	Proxy
prod	The following equation is used to calculate productivity: $$Productivity = \frac{Value\ Added\ at\ Factor\ Costs}{Number\ of\ Employees}$$	Dependent variable representing sectoral-level productivity.
fdi	The FDI inflow to each sector in Turkish lira. The natural logarithm of this value has been taken.	Source of capital and technological spillovers.
fdi_code	Represents the aggregated 14 sector codes listed in Table 1. Shows the interaction between the sector's FDI inflow and the sector ID.	Sectoral Absorptive Capacity
fdi_lag	The lagged FDI inflow (t-1) for each sector in Turkish lira.	Source of capital and technological spillovers.
fdi_lag _code	Represents the aggregated 14 sector codes listed in Table 1. Shows the interaction between the lagged FDI inflow (t-1) and the sector ID.	Sectoral Absorptive Capacity
person_ cost_pp	The ratio of total personnel costs to the number of personnel in each sector, calculated in Turkish lira.	Human Capital
turnover_in	The turnover index for each sector.	Economic Dynamism
ex_im_cov	The export-to-import coverage ratio for each sector. This ratio is calculated by dividing exports by imports (exports as the numerator, imports as the denominator).	Trade flows
purchase_ commercial	The purchases of commercial goods in each sector, calculated in Turkish lira. The natural logarithm of this value has been taken.	Input Utilization and operational capital

2.3 Econometric Model

This study employs a multi-stage empirical strategy to comprehensively investigate the FDI-productivity nexus. The analysis begins with preliminary estimations to establish baseline relationships, followed by a more advanced dynamic panel model to capture the complex temporal dynamics.

The first stage involves an examination of short-run correlations using a panel model on first-differenced variables. In the second stage, the long-run cointegrating relationship between the variables is investigated using established panel cointegration estimators, namely Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS). These methods are robust to serial correlation and endogeneity and provide a baseline for the long-run effects.

As a complementary dynamic approach to the static models, this study also utilizes the Panel Autoregressive Distributed Lag (ARDL) model. The estimations are carried out using the Pooled Mean Group (PMG) estimator from Pesaran, Shin, and Smith (1999) to provide insights into both short- and long-run adjustments. This dynamic approach is chosen for several key reasons. First, it is well-suited for panels with variables integrated of different orders, I(0) or I(1). Second, and most importantly, it allows for the simultaneous estimation of both the long-run equilibrium relationship and the heterogeneous short-run dynamics for each individual sector.

In the econometric estimation, multiple models were employed to ensure the robustness of the results. However, the study's two primary models can be generalized as follows:

$$\boldsymbol{prod_{i,t}} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}\text{person\_cost\_pp}_{i,t} + \boldsymbol{\beta_2}\text{turnover\_in}_{i,t} + \boldsymbol{\beta_3}\text{ex\_im\_cov}_{i,t} + \boldsymbol{\beta_4}\text{purchase\_commercial}_{i,t} + \boldsymbol{\beta_5}\text{fdi}_{i,t} + \boldsymbol{\beta_6}\text{fdi\_code}_{i,t} + \varepsilon_{i,t} \tag{10}$$

$$\boldsymbol{prod_{i,t}} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}\text{person\_cost\_pp}_{i,t} + \boldsymbol{\beta_2}\text{turnover\_in}_{i,t} + \boldsymbol{\beta_3}\text{ex\_im\_cov}_{i,t} + \boldsymbol{\beta_4}\text{purchase\_commercial}_{i,t} + \boldsymbol{\beta_5}\text{fdi}_{i,(t-1)} + \boldsymbol{\beta_6}\text{fdi\_lag\_code}_{i,(t)} + \varepsilon_{i,t} \tag{11}$$

Prior to estimation, a series of diagnostic checks were conducted. Panel unit root tests (LLC, IPS, and Fisher-type) were performed to determine the integration order of the variables. For completeness, a cross-sectional dependence (CSD) test was also conducted; given the short time dimension of the panel (T=14), its results are presented in the Appendix for reference. Cointegration among the I(1) variables was confirmed using the Kao and Pedroni panel cointegration tests, justifying the use of an error-correction framework like Panel ARDL.

2.4 Methodological Limitations

While the employed multi-stage approach enhances the robustness of the findings, the study acknowledges certain limitations, primarily related to the short time dimension of the available data, which results in a significant loss of degrees of freedom when estimating complex models. This was particularly evident in preliminary attempts to use sector-specific interaction terms, where the proliferation of variables made robust estimation for the entire panel challenging. This constraint makes the estimation of models with extensive lag structures impractical and was a key reason for selecting a maximum lag of 1 in the final ARDL specification. Furthermore, while the PMG estimator effectively models heterogeneous short-run dynamics, its assumption of homogenous long-run coefficients across all sectors is a simplifying one. The inability of the DOLS and FMOLS estimators to model long-run sectoral interactions, and the challenges of estimating a Mean Group ARDL model with a short T, mean that the specific long-run effects for each individual sector remain an area for future research with longer time-series data. The findings of this study should therefore be interpreted in light of these constraints. It is precisely because of these limitations that a multi-stage empirical strategy—employing Random Effects, FMOLS/DOLS, and Panel ARDL estimators—was utilized to ensure the conclusions are robust and not dependent on a single model specification.

3. Results and Discussions

3.1 Pre-estimation Diagnostics

The empirical analysis commenced with a series of diagnostic tests to determine the underlying properties of the panel data and to guide the selection of the appropriate econometric models.

First, the presence of cross-sectional dependence (CSD) was examined. Pesaran (2004, p. 1-39) developed a cross-section dependence (CD) test to detect whether there is correlation among cross-sectional units in a panel dataset. The null hypothesis of the CD test states that there is no cross-section dependence While the test was performed for completeness, it is acknowledged that its power may be limited in panels with a short time dimension, such as the T=14 period in this study. The results, which are reported in Appendix for reference, indicated that the null hypothesis of no cross-section dependence could not be rejected for the variables. Consequently, first-generation panel unit root tests were deemed appropriate for the stationarity analysis.

The stationarity properties of the variables were examined next. As established in the seminal work of Granger and Newbold (1974, p. 111-120), using non-stationary variables in regression analysis can lead to spurious results; therefore identifying the order of integration for each series is a critical preliminary step. To this end, stationarity was tested using the Levin, Lin, and Chu (2002, p. 1-24), Phillips-Perron (1988, p. 335-346), and Augmented Dickey-Fuller (1979, p. 427-431) tests. The null hypothesis (H0) of these stationarity tests is that the series has a unit root, indicating non-stationarity. The results, as illustrated in Table 3, indicated that all variables were non-stationary at level I(0). However, after taking the first differences (I(1)), the variables became stationary. These findings confirm that the variables are integrated of order one, fulfilling a key prerequisite for employing panel cointegration techniques such as FMOLS, DOLS, and the Panel ARDL model.

Table 3: *Results of Unitroot Tests*

Variable	LLC*		PP**		ADF***		Variable	LLC		PP		ADF	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
fdi	1.00	0.00	1.00	0.00	0.41	0.00	**prod**	0.76	0.00	0.99	0.00	0.99	0.00
fdi_CA	1.00	0.00	0.79	0.00	0.99	0.00	**fdi_CH**	1.00	0.00	1.00	0.00	1.00	0.00
fdi_CB	1.00	0.00	1.00	0.00	1.00	0.00	**fdi_CI**	1.00	0.00	1.00	0.00	1.00	0.00
fdi_CC	1.00	0.00	1.00	0.00	1.00	0.00	**fdi_CJ**	1.00	0.00	1.00	0.00	1.00	0.00
fdi_CD	1.00	0.00	1.00	0.00	1.00	0.00	**fdi_CK**	1.00	0.00	1.00	0.00	0.99	0.00
fdi_CE	1.00	0.00	1.00	0.00	1.00	0.00	**fdi_CL**	1.00	0.00	1.00	0.00	1.00	0.00
fdi_CF	1.00	0.00	1.00	0.00	1.00	0.00	**fdi_CM**	1.00	0.00	1.00	0.00	1.00	0.00
fdi_CG	1.00	0.00	1.00	0.00	1.00	0.00	**fdi_CN**	1.00	0.00	1.00	0.00	1.00	0.00
fdi_lag	0.81	0.00	1.00	0.00	0.20	0.00	**fdi_lag_CH**	1.00	0.00	1.00	0.00	1.00	0.00
fdi_lag_CA	1.00	0.00	0.86	0.00	1.00	0.00	**fdi_lag_CI**	1.00	0.00	1.00	0.00	1.00	0.00
fdi_lag_CB	1.00	0.00	0.99	0.00	1.00	0.00	**fdi_lag_CJ**	1.00	0.00	1.00	0.00	1.00	0.00
fdi_lag_CC	1.00	0.00	1.00	0.00	1.00	0.00	**fdi_lag_CK**	1.00	0.00	1.00	0.00	1.00	0.00
fdi_lag_CD	1.00	0.00	1.00	0.00	1.00	0.00	**fdi_lag_CL**	1.00	0.00	1.00	0.00	1.00	0.00
fdi_lag_CE	1.00	0.00	1.00	0.00	1.00	0.00	**fdi_lag_CM**	1.00	0.00	1.00	0.00	1.00	0.00
fdi_lag_CF	1.00	0.00	1.00	0.00	1.00	0.00	**fdi_lag_CN**	1.00	0.00	1.00	0.00	1.00	0.00
fdi_lag_CG	1.00	0.00	0.99	0.00	1.00	0.00	**ex_im_cov**	0.17	0.00	0.70	0.00	0.73	0.00
person _cost_pp	0.21	0.00	0.32	0.00	0.97	0.00	**purchase _commercial**	0.29	0.00	0.19	0.00	0.30	0.00
turnover_in	1.00	0.00	1.00	0.00	1.00	0.00							

*LLC: Levin, Lin, Chu Test, ** PP: Phillips-Perron Test, *** ADF: Augmented Dickey-Fuller Test

Source: Own calculations.

To ensure that the long-run models are well-specified, the variables were also checked for potential multicollinearity. In this study, the correlation matrix of the variables was analyzed and presented in Table 4 and Table 5. It was determined that no correlation exceeded 0.70, indicating that multicollinearity is unlikely to affect the estimations (Dancey & Reidy, 2017, p. 181-182)[2].

Table 4: *Coefficient Correlation Matrix – With FDI and Interaction Terms*

Variables	prod	per_cost	turnover	ex_im_cov	purch_com	fdi	fdi_CA	fdi_CA	fdi_CA	fdi_CA	fdi_CA	fdi_CA	fdi_CA	fdi_CA	fdi_CA	fdi_CA	fdi_CA	fdi_CA	fdi_CA	fdi_CA
prod	1.0000																			
per_cost	0.5924	1.0000																		
turnover	0.0082	-0.2421	1.0000																	
ex_im_cov	-0.3535	-0.3929	0.0571	1.0000																
purch_com	0.0826	0.1065	0.0501	0.4052	1.0000															
fdi	0.3496	0.3843	0.0751	-0.0432	0.3906	1.0000														
fdi_CA	-0.1338	-0.1509	-0.0178	0.1857	0.3047	0.4988	1.0000													
fdi_CB	-0.1522	-0.1756	0.0258	0.6019	0.4409	-0.1618	-0.0617	1.0000												
fdi_CC	-0.1612	-0.1488	-0.0617	-0.0718	-0.2236	-0.1788	-0.0549	-0.0493	1.0000											
fdi_CD	-0.0574	-0.0721	-0.0554	-0.0928	-0.1524	-0.1293	-0.0422	-0.0379	-0.0338	1.0000										
fdi_CE	0.0035	0.0085	0.0440	-0.1118	-0.1129	-0.0659	-0.0488	-0.0438	-0.0390	-0.0300	1.0000									
fdi_CF	0.4505	0.2938	0.2249	-0.2174	-0.2827	0.0928	-0.0664	-0.0597	-0.0531	-0.0408	-0.0472	1.0000								
fdi_CG	0.4046	0.3217	-0.0069	-0.2359	0.2037	0.2484	-0.0647	-0.0581	-0.0517	-0.0398	-0.0459	-0.0626	1.0000							
fdi_CH	-0.0476	-0.0761	0.0901	0.0719	-0.0440	0.0319	-0.0618	-0.0555	-0.0494	-0.0380	-0.0439	-0.0598	-0.0582	1.0000						
fdi_CI	-0.0954	-0.1259	-0.0481	0.2498	-0.1281	-0.0660	-0.0619	-0.0556	-0.0495	-0.0380	-0.0440	-0.0599	-0.0583	-0.0557	1.0000					
fdi_CJ	-0.1106	-0.1907	0.0814	-0.1048	0.1532	-0.0169	-0.0668	-0.0600	-0.0534	-0.0411	-0.0475	-0.0646	-0.0629	-0.0601	-0.0602	1.0000				
fdi_CK	-0.0560	-0.0522	-0.0242	-0.1196	-0.0685	-0.0739	-0.0384	-0.0345	-0.0307	-0.0236	-0.0273	-0.0371	-0.0361	-0.0345	-0.0346	-0.0373	1.0000			
fdi_CL	0.0740	0.1843	-0.0338	-0.1780	0.0303	0.1780	-0.0672	-0.0604	-0.0537	-0.0413	-0.0478	-0.0650	-0.0633	-0.0605	-0.0606	-0.0654	-0.0376	1.0000		
fdi_CM	0.3018	0.4735	-0.0496	-0.0592	0.2637	0.5025	-0.0663	-0.0595	-0.0530	-0.0407	-0.0471	-0.0641	-0.0624	-0.0596	-0.0597	-0.0645	-0.0370	-0.0649	1.0000	
fdi_CN	-0.1021	-0.1106	0.0870	0.1561	-0.0342	0.3251	-0.0389	-0.0350	-0.0311	-0.0239	-0.0277	-0.0377	-0.0367	-0.0350	-0.0351	-0.0379	-0.0218	-0.0381	-0.0376	1.0000

Source: Own calculations.

[2] Furthermore, the algorithm of the Stata 16 software used in the analysis automatically excludes collinear variables during the estimation process, providing an additional safeguard against multicollinearity.

Table 5: *Coefficient Correlation Matrix – With Lagged FDI (t-1) and Interaction Terms*

Variables	prod	per_cost	turnover	ex_im_cov	purch_com	fdi_lag	fdi_lag_CA	fdi_lag_CB	fdi_lag_CC	fdi_lag_CD	fdi_lag_CE	fdi_lag_CF	fdi_lag_CG	fdi_lag_CH	fdi_lag_CI	fdi_lag_CJ	fdi_lag_CK	fdi_lag_CL	fdi_lag_CM	fdi_lag_CN
prod	1.0000																			
per_cost	0.5924	1.0000																		
turnover	0.0082	-0.2421	1.0000																	
ex_im_cov	-0.3535	-0.3929	0.0571	1.0000																
purch_com	0.0826	0.1065	0.0501	0.4052	1.0000															
fdi_lag	0.3647	0.4140	0.0057	-0.0772	0.4700	1.0000														
fdi_lag_CA	-0.1327	-0.1535	-0.0209	0.1846	0.4068	0.5938	1.0000													
fdi_lag_CB	-0.1327	-0.1926	-0.0290	0.6047	0.4605	-0.2086	-0.0690	1.0000												
fdi_lag_CC	-0.1614	-0.1465	-0.0622	-0.0511	-0.2275	-0.1941	-0.0550	-0.0557	1.0000											
fdi_lag_CD	-0.0571	-0.0824	-0.0468	-0.0694	-0.1653	-0.1440	-0.0437	-0.0442	-0.0352	1.0000										
fdi_lag_CE	0.0066	-0.0313	0.0232	-0.1060	-0.1187	-0.0617	-0.0464	-0.0470	-0.0375	-0.0297	1.0000									
fdi_lag_CF	0.4372	0.2157	0.3200	-0.2180	-0.2978	0.1383	-0.0666	-0.0674	-0.0538	-0.0427	-0.0454	1.0000								
fdi_lag_CG	0.4385	0.3786	-0.0572	-0.2607	0.1761	0.1383	-0.0704	-0.0713	-0.0568	-0.0451	-0.0479	-0.0688	1.0000							
fdi_lag_CH	-0.0557	-0.0791	0.0550	0.0722	-0.0575	-0.0109	-0.0662	-0.0670	-0.0534	-0.0424	-0.0451	-0.0647	-0.0683	1.0000						
fdi_lag_CI	-0.0951	-0.1217	-0.0452	0.2215	-0.1279	-0.0565	-0.0627	-0.0635	-0.0506	-0.0401	-0.0427	-0.0613	-0.0647	-0.0609	1.0000					
fdi_lag_CJ	-0.1061	-0.1969	0.0535	-0.1106	0.1511	0.0015	-0.0661	-0.0669	-0.0533	-0.0423	-0.0450	-0.0646	-0.0682	-0.0642	-0.0608	1.0000				
fdi_lag_CK	-0.0559	-0.0408	-0.0505	-0.1187	-0.0727	-0.0669	-0.0361	-0.0366	-0.0291	-0.0231	-0.0246	-0.0353	-0.0373	-0.0350	-0.0332	-0.0350	1.0000			
fdi_lag_CL	0.0731	0.2042	-0.0716	-0.1838	0.0187	0.1884	-0.0681	-0.0689	-0.0549	-0.0436	-0.0464	-0.0665	-0.0703	-0.0661	-0.0626	-0.0660	-0.0361	1.0000		
fdi_lag_CM	0.3052	0.5262	-0.0845	-0.0667	0.2797	0.4673	-0.0702	-0.0711	-0.0567	-0.0450	-0.0478	-0.0686	-0.0725	-0.0682	-0.0646	-0.0681	-0.0372	-0.0701	1.0000	
fdi_lag_CN	-0.1351	0.1318	0.0170	0.1812	-0.0599	0.4673	-0.0480	-0.0486	-0.0388	-0.0308	-0.0327	-0.0469	-0.0496	-0.0466	-0.0442	-0.0465	-0.0254	-0.0480	-0.0495	1.0000

Source: Own calculations.

Finally, the presence of serial correlation in the panel was examined. Autocorrelation in panel data can lead to biased and inefficient estimators, compromising the reliability of the results. The Wooldridge (2002) test for autocorrelation was conducted to detect the presence of such issues and ensure the robustness of the estimation process. The test results indicate the presence of first-order autocorrelation in the models, with p-values of 0.0007 and 0.0432 for the specifications with contemporaneous and lagged FDI, respectively. In both cases, the null hypothesis of no first-order autocorrelation is rejected. In both cases, the null hypothesis of no first-order autocorrelation is rejected. Therefore, estimations in this study will have clustered standard errors which tackle with autocorrelation and heteroskedasticity problems.

Given that the variables were found to be I(1), panel cointegration tests were conducted to determine if a stable long-run relationship exists among them. The results from both the Kao (1999) and Pedroni (1999, 2004) tests, presented in the subsequent section, confirmed the presence of cointegration, justifying the use of error-correction based models like DOLS, FMOLS, and Panel ARDL.

3.2 Preliminary Short-Run Analysis: Random Effects Model

To begin the empirical investigation, the relationship between the variables was first explored using standard panel data models. A Hausman (1978, p. 1251-1271) test was conducted to determine the most appropriate model—fixed or random effects—for panel data analysis. By comparing estimators, the test identifies the most efficient and consistent method. The null hypothesis (H0) of the Hausman test (1978, p. 1251-1271) is that the random effects model is the most efficient estimator, implying no correlation between individual effects and the regressors. The results of the test indicate that the random-effects model is the most efficient specification for analyzing both the manufacturing FDI and its subsectors, as well as the lagged FDI and its subsectors, with a p-value of 1.0000 for each model. Results for both FDI and its t-1 lagged variation are illustrated in Table 6 and Table 7.

The estimation results from these Random Effects models reveal a diverse set of relationships between productivity and the independent variables. Personnel cost per person exhibits a significant positive relationship with productivity, suggesting that investments in human capital contribute to improved efficiency and output. Conversely, the turnover index shows a significant negative effect, indicating that higher turnover may disrupt production processes and negatively impact productivity. Both the export/import coverage ratio and the purchase of commercial goods are found to be statistically insignificant, implying that these factors do not have a direct or measurable effect on productivity within the context of these static short-run models.

FDI demonstrates a significant positive relationship with productivity at the aggregate level, underscoring the potential benefits of FDI in enhancing technological capabilities, improving management practices, and fostering innovation. However, when analyzed at the sectoral level using interaction terms, the results reveal heterogeneity. FDI inflows into sectors such as CH, CK, CM, and CN are positively associated with productivity, reflecting substantial spillover effects and alignment with domestic capacities. In contrast, FDI inflows into sectors CD, CE, CI, and CL exhibit a significant negative relationship with productivity, potentially due to crowding-out effects or misalignment with the needs of the domestic economy. For other sectors (CA, CB, CC, CF, CG, CJ), FDI inflows are statistically insignificant, suggesting limited integration or weak spillovers.

The estimation results for the lagged FDI variables provide insights into the dynamic effects of FDI on productivity. As in the previous model, personnel cost per person maintains a significant positive relationship with productivity, reaffirming the critical role of human capital investments. Similarly, the turnover index retains its significant negative effect, indicating the adverse impact of workforce instability on production efficiency.

The export/import coverage ratio and purchase of commercial goods remain statistically insignificant, suggesting limited direct influence on productivity in the lagged framework. Interestingly, the overall lagged FDI variable **(**fdi_lag**)** is also found to be insignificant, implying that the aggregate delayed effect of FDI inflows may not directly affect productivity in the short term. However, a more nuanced analysis at the sectoral level reveals significant results.

FDI inflows into sectors such as CA and CN show significant negative relationships with productivity, potentially indicating delayed crowding-out effects, adjustment costs, or mismatches between sectoral investment priorities and domestic absorptive capacities. Lagged FDI inflows into several sectors, including CD**,** CE**,** CF**,** CG**,** CI**,** CJ**,** CK**,** CL**,** and CM, exhibit significant positive relationships with productivity. These results suggest that the benefits of FDI, such as technology transfer and capacity-building, may take time to materialize in these sectors. In sectors such as CB**,** CC, and CH**,** lagged FDI inflows remain statistically insignificant, indicating limited or inconsistent delayed impacts on productivity.

Table 6: *Random Effects Estimations with Current FDI as Independent Variable*

Variables	(1) Model	(2) Model	(3) Model	(4) Model	(5) Model	(6) Model	(7) Model	(8) Model	(9) Model	(10) Model	(11) Model	(12) Model	(13) Model	(14) Model	(15) Model	(16) Model	(17) Model	(18) Model	(19) Model	(20) Model
D.person_cost_pp	1.822***		2.718***	1.823***	1.806***	1.634***	1.681***	1.677***	1.674***	1.679***	1.688***	1.778***	1.675***	1.669***	1.674***	1.673***	1.675***	1.677***	1.672***	1.673***
	(0.346)		(0.601)	(0.327)	(0.347)	(0.121)	(0.127)	(0.127)	(0.126)	(0.123)	(0.113)	(0.353)	(0.126)	(0.127)	(0.126)	(0.126)	(0.125)	(0.124)	(0.127)	(0.127)
D.turnover_in	-26.71***	-34.07***		-26.69***	-26.92***	-26.68***	-26.21***	-26.31***	-26.27***	-26.28***	-26.17***	-26.33***	-26.29***	-26.46***	-26.27***	-26.30***	-26.37***	-26.21***	-26.33***	-26.45***
	(8.988)	(11.05)		(9.264)	(9.079)	(8.368)	(8.513)	(8.573)	(8.573)	(8.571)	(8.634)	(8.743)	(8.606)	(8.509)	(8.570)	(8.569)	(8.551)	(8.643)	(8.544)	(8.505)
D.ex_im_cov	-130.9	-1,918	3,169		-473.7	-786.8	-1,124	-926.9	-1,326	-1,443	-1,318	-1,331	-1,337	-1,246	-1,339	-1,297	-1,383	-1,351	-1,240	-964.8
	(2,573)	(1,268)	(4,213)		(2,303)	(1,916)	(1,922)	(1,955)	(1,717)	(1,671)	(1,710)	(1,751)	(1,708)	(1,768)	(1,714)	(1,737)	(1,704)	(1,710)	(1,747)	(1,840)
D.purchase_commercial	1.55e-06	1.36e-06	1.83e-06	1.55e-06		1.03e-06	1.49e-06	7.90e-07	7.76e-07	7.78e-07	7.82e-07	7.76e-07	7.72e-07	7.76e-07	7.77e-07	7.64e-07	7.77e-07	7.81e-07	7.49e-07	7.89e-07
	(1.27e-06)	(1.22e-06)	(1.56e-06)	(1.23e-06)		(6.43e-07)	(1.17e-06)	(6.96e-07)	(6.79e-07)	(6.80e-07)	(6.82e-07)	(6.76e-07)	(6.73e-07)	(6.78e-07)	(6.80e-07)	(6.72e-07)	(6.80e-07)	(6.81e-07)	(6.61e-07)	(6.89e-07)
D.fdi	0.485***					0.334***														
	(0.175)					(0.123)														
D.fdi_CA	0.346	0.694	1.012	0.834	-0.0650***		0.790													
	(0.609)	(0.713)	(0.927)	(0.715)	(0.0192)		(0.687)													
D.fdi_CB	4.958	3.727	3.151	5.554*	4.195			3.962												
	(4.785)	(3.878)	(5.017)	(2.954)	(4.132)			(3.751)												
D.fdi_CC	47.22	99.06***	57.83	49.60***	37.68				34.27											
	(31.88)	(21.82)	(44.62)	(10.30)	(23.81)				(25.95)											
D.fdi_CD	-12.61***	-4.404**	-10.99***	-12.05***	-11.78***					-11.87***										
	(2.296)	(1.711)	(1.648)	(3.362)	(1.919)					(1.237)										
D.fdi_CE	-1.689***	0.319***	-2.259***	-1.204***	-1.101***						-1.075***									
	(0.383)	(0.109)	(0.517)	(0.219)	(0.181)						(0.0933)									
D.fdi_CF	-1.724	4.293***	-0.870	-1.239	-1.225							-1.049								
	(2.492)	(1.449)	(2.102)	(2.309)	(2.348)							(2.327)								
D.fdi_CG	-0.427***	-0.105	-0.448***	0.0578	0.199								0.0788							
	(0.0915)	(0.205)	(0.111)	(0.203)	(0.276)								(0.182)							
D.fdi_CH	1.014***	1.730***	0.251	1.503***	1.490***									1.418***						
	(0.375)	(0.622)	(0.226)	(0.483)	(0.548)									(0.471)						
D.fdi_CI	-0.957***	-0.743***	-0.170	-0.468**	-0.239										-0.357**					
	(0.293)	(0.241)	(0.191)	(0.206)	(0.183)										(0.141)					
D.fdi_CJ	-0.351	0.356	-0.743*	0.139	0.645											0.329				
	(0.268)	(0.266)	(0.389)	(0.248)	(0.432)											(0.280)				
D.fdi_CK	2.281***	2.337***	1.028***	2.761***	2.753***												2.744***			
	(0.758)	(0.885)	(0.247)	(1.020)	(0.901)												(0.777)			
D.fdi_CL	-0.840***	-0.134	-0.917***	-0.353***	-0.286													-0.351**		
	(0.0672)	(0.200)	(0.0657)	(0.134)	(0.189)													(0.159)		
D.fdi_CM	-0.194	0.351***	0.0765	0.293***	0.422***														0.335***	
	(0.177)	(0.0779)	(0.102)	(0.0762)	(0.106)														(0.0676)	
D.fdi_CN	0	0.467***	0.266**	0.488***	0.459***															0.446***
	(0)	(0.163)	(0.127)	(0.131)	(0.159)															(0.135)
Constant	2,831***	3,269***	425.5	2,823***	3,248***	2,965***	2,941***	3,101***	3,142***	3,147***	3,142***	3,169***	3,140***	3,101***	3,138***	3,148***	3,184***	3,152***	3,118***	3,086***
	(747.4)	(735.8)	(653.4)	(878.3)	(952.0)	(766.6)	(703.6)	(786.0)	(818.4)	(818.3)	(823.4)	(900.6)	(812.5)	(804.0)	(819.5)	(820.7)	(822.6)	(816.6)	(810.6)	(804.3)
Number of pid	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Own calculations.

Table 7: *Random Effects Estimations with FDI(t-1) as Independent Variable*

Variables	(1) Model	(2) Model	(3) Model	(4) Model	(5) Model	(6) Model	(7) Model	(8) Model	(9) Model	(10) Model	(11) Model	(12) Model	(13) Model	(14) Model	(15) Model	(16) Model	(17) Model	(18) Model	(19) Model	(20) Model
D.person_cost_pp	1.659***		2.250***	1.646***	1.642***	1.716***	1.676***	1.680***	1.678***	1.684***	1.735***	1.537***	1.696***	1.680***	1.684***	1.692***	1.679***	1.685***	1.682***	1.679***
	(0.0727)		(0.197)	(0.0521)	(0.0510)	(0.104)	(0.119)	(0.117)	(0.120)	(0.119)	(0.0680)	(0.176)	(0.108)	(0.118)	(0.119)	(0.117)	(0.119)	(0.115)	(0.117)	(0.121)
D.turnover_in	-18.13***	-28.09***		-18.42***	-18.23**	-25.49***	-27.18***	-26.78***	-26.80***	-26.73***	-26.21***	-18.66***	-26.64***	-26.78***	-26.89***	-26.86***	-26.81***	-26.72***	-26.77***	-26.88***
	(6.452)	(8.609)		(7.015)	(7.106)	(8.044)	(8.296)	(8.428)	(8.398)	(8.416)	(8.870)	(5.729)	(8.484)	(8.432)	(8.356)	(8.363)	(8.403)	(8.455)	(8.414)	(8.376)
D.ex_im_cov	1,436	-1,276	4,938			-2,773	-2,499	-2,635	-2,528	-2,296	-2,460	-131.6	-2,444	-2,518	-2,125	-2,580	-2,525	-2,496	-2,402	-1,916
	(4,238)	(2,239)	(6,068)			(1,834)	(1,908)	(2,003)	(1,825)	(2,041)	(1,784)	(2,916)	(1,813)	(1,824)	(1,917)	(1,823)	(1,816)	(1,815)	(1,827)	(2,135)
D.purchase_commercial	1.13e-06	1.08e-06	1.04e-06	1.13e-06		3.91e-07	1.22e-06	8.13e-07	8.23e-07	8.22e-07	8.39e-07	8.70e-07	8.28e-07	8.20e-07	8.21e-07	8.14e-07	8.23e-07	8.03e-07	7.51e-07	8.38e-07
	(9.79e-07)	(9.04e-07)	(1.07e-06)	(9.60e-07)		(3.98e-07)	(8.29e-07)	(7.24e-07)	(7.21e-07)	(7.20e-07)	(7.28e-07)	(7.99e-07)	(7.24e-07)	(7.21e-07)	(7.21e-07)	(7.15e-07)	(7.22e-07)	(7.10e-07)	(6.84e-07)	(7.36e-07)
D.fdi_lag	-0.769*					0.698														
	(0.465)					(0.718)														
D.fdi_lag_CA	0.142	-0.652	-0.380	-0.625	-0.252**		-0.772**													
	(0.229)	(0.403)	(0.370)	(0.397)	(0.102)		(0.374)													
D.fdi_lag_CB	1.748	-0.979	2.662	2.211	4.229***			3.421												
	(5.828)	(4.710)	(6.557)	(2.914)	(1.412)			(4.150)												
D.fdi_lag_CC	-54.92*	-149.1***	27.63	-70.14***	-54.56***				-102.4***											
	(28.12)	(22.04)	(49.89)	(24.63)	(14.12)				(18.44)											
D.fdi_lag_CD	14.75*	2.880	23.33**	11.33***	11.34***					6.858*										
	(7.980)	(3.743)	(11.56)	(0.399)	(0.405)					(3.629)										
D.fdi_lag_CE	3.303***	-0.633	4.581***	2.518***	2.432***						2.153***									
	(0.243)	(0.541)	(0.279)	(0.398)	(0.462)						(0.565)									
D.fdi_lag_CF	11.48***	11.32***	13.04***	10.65***	10.66***							10.76***								
	(0.683)	(1.430)	(0.152)	(1.204)	(1.234)							(1.111)								
D.fdi_lag_CG	2.008***	0.327***	1.737***	1.220***	1.185***								1.126***							
	(0.483)	(0.0564)	(0.176)	(0.0518)	(0.0694)								(0.0664)							
D.fdi_lag_CH	1.252***	-0.181	1.194***	0.508	0.663***									0.312						
	(0.125)	(0.413)	(0.192)	(0.334)	(0.224)									(0.407)						
D.fdi_lag_CI	4.252**	2.770**	2.713**	3.223***	3.201***										3.748***					
	(1.897)	(1.163)	(1.210)	(0.698)	(0.698)										(1.228)					
D.fdi_lag_CJ	2.601***	1.268***	1.613***	1.848***	1.884***											2.146***				
	(0.578)	(0.180)	(0.0396)	(0.164)	(0.190)											(0.233)				
D.fdi_lag_CK	1.175*	0.230	-0.241	0.451	0.352												0.904**			
	(0.661)	(0.300)	(0.303)	(0.333)	(0.265)												(0.449)			
D.fdi_lag_CL	1.727***	0.567***	1.243***	0.953***	1.081***													0.921***		
	(0.342)	(0.166)	(0.0916)	(0.157)	(0.0591)													(0.137)		
D.fdi_lag_CM	1.721***	0.858***	1.014***	0.938***	1.144***														0.995***	
	(0.396)	(0.141)	(0.143)	(0.164)	(0.0217)														(0.112)	
D.fdi_lag_CN	0	-0.736**	-0.615	-0.674***	-0.615***															-0.724**
	(0)	(0.354)	(0.466)	(0.199)	(0.162)															(0.345)
Constant	2,302***	3,141***	332.4	2,401***	2,636***	3,503***	3,499***	3,556***	3,553***	3,536***	3,497***	2,456***	3,521***	3,546***	3,588***	3,594***	3,569***	3,541***	3,532***	3,536***
	(340.2)	(513.7)	(894.8)	(521.3)	(655.0)	(785.9)	(790.9)	(824.1)	(826.7)	(826.4)	(870.5)	(331.2)	(830.7)	(835.8)	(827.6)	(823.8)	(832.3)	(832.4)	(826.5)	(817.0)
Number of pid	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Own calculations.

The comparison between the current and lagged FDI models highlights significant differences in how FDI influences productivity across Türkiye's manufacturing sectors. While current FDI shows a positive relationship with productivity at the aggregate level, lagged FDI reveals a more nuanced pattern, with both positive and negative effects across sectors. These variations underscore the dynamic and sector-specific nature of FDI impacts, influenced by the timing of benefits, absorptive capacities, and structural characteristics of each industry.

In technologically advanced and capital-intensive sectors such as machinery and equipment (CK)**,** transportation equipment (CM) and chemicals and pharmaceuticals **(CG)**, FDI consistently correlates positively with productivity in both current and lagged models. These sectors are better positioned to integrate foreign investment benefits, such as technology transfer, process improvements, and enhanced managerial practices, sustaining productivity gains over time. The non-metallic mineral products (CI) sector also shows positive effects in the lagged model, suggesting that these industries require time to fully capitalize on FDI's potential.

In contrast, sectors like food, beverage, and tobacco (CA)**,** paper and printing (CE) and basic metal industries (CJ) exhibit mixed results. The positive effects of FDI in the current model transition to negative or insignificant impacts in the lagged model for some, reflecting challenges such as market saturation, adjustment costs, or diminishing returns over time. For the rubber and plastic products (CH) and textiles and apparel (CB) sectors, FDI remains insignificant across both models, indicating structural barriers like low innovation capacity or over-reliance on cost-competitive strategies that hinder the realization of FDI's productivity-enhancing potential.

Interestingly, some sectors display opposite effects between the two models. For example, wood and wood products (CD) and computer, electronics, and optical products (CL) experience negative impacts of current FDI but positive impacts in the lagged model. This pattern may indicate initial disruptions due to foreign investment, such as restructuring processes or competition with domestic firms, which eventually result in efficiency gains.

On the other hand, furniture and other manufacturing (CN) **s**hows positive effects in the current model but negative effects in the lagged model, suggesting potential overinvestment or declining marginal returns over time.

The leather and related products (CC) sector remains consistently insignificant, highlighting persistent challenges in leveraging FDI effectively, possibly due to limited scalability or reliance on low-value-added production. Similarly, the coke and refined petroleum products (CF) sector benefits from lagged FDI but shows no significant immediate effects, likely due to the capital-intensive and long-term nature of investments in this industry.

The preceding analysis, based on static Random Effects models, successfully highlights two crucial points: first, the significant heterogeneity of FDI's short-run impact across different manufacturing sectors, and second, the differing results when using contemporaneous versus lagged variables, which underscores the importance of temporal dynamics. However, this approach has inherent limitations. As a static framework applied to first-differenced data, it cannot model the long-run equilibrium relationship between the variables, nor can it estimate the speed at which sectors correct for deviations from this equilibrium. To build upon these initial findings and provide a more comprehensive analysis that integrates these dynamic aspects, the subsequent sections employ panel cointegration techniques and the Panel ARDL model.

3.3 Long-Run Cointegration and Static Panel Estimations

Establishing cointegration is critical for analyzing long-term relationships between non-stationary variables. The Pedroni (1999, p. 653-670) and Kao (1999, p. 1-44) tests are commonly used to assess whether the variables exhibit a stable, long-term equilibrium relationship[3]. Cointegration ensures that, despite short-term fluctuations, the variables move together over time. The null hypothesis (H0) of the Pedroni (1999, p. 653-670) and Kao (1999, p. 1-44) cointegration tests is that there is no cointegration among the variables, suggesting no long-term relationship exists. The Pedroni (1999, p. 653-670) test could not be applied to the general econometric model due to its inclusion of more than seven variables. However, the Kao (1999, p. 1-44) test allows for such estimation.

Table 8: *Kao (1999) Co-Integration Test Results for General Models*

Specification*	Test Statistic	Value	p-value	Interpretation
Model 1: Without lags on FDI	Modified Dickey-Fuller	0.5946	0.2761	Fail to reject H0, no cointegration.
Model 2: With lagged FDI	Modified Dickey-Fuller	1.9450	0.0259	Reject H0, evidence of cointegration.

*Model 1 and Model 2 refers equations (10) and (11), respectively.
Source: Own calculations.

For both general models, the Kao (1999, p. 1-44) test results, illustrated in Table 8, indicate no cointegration or long-term relationship between sectoral FDI and productivity. Nevertheless, a statistically significant relationship was found between lagged FDI and productivity. Consequently, the study focuses on lagged FDI inflows to manufacturing sub-sectors to explore the long-term relationship between FDI and productivity. In this context, both Kao (1999, p. 1-44) and Pedroni (1999, p. 653-670) tests were reapplied, with results presented in Table 9.

For the Kao (1999, p. 1-44) test, the null hypothesis (H0) of no co-integration is rejected for all variables at varying levels of significance. This suggests the existence of a long-term equilibrium relationship between productivity and lagged FDI across all sectors. The rejection of H0 in both modified and standard statistics indicates the robustness of this finding, even though some test statistics approach the significance threshold.

Pedroni (1999, p. 653-670) test yields more mixed results, with co-integration established for the aggregate lagged FDI variable but not consistently across all sectoral interactions. For certain sectors, such as CD (Wood and Wood Products), co-integration is strongly supported by both modified and standard statistics. Conversely, sectors like CF (Coke and Refined Petroleum) and CL (Computer, Electrical, and Optical Products) show no evidence of co-integration, as H0 cannot be rejected in either test statistic. This inconsistency across sectors may reflect structural differences in how FDI impacts productivity over time, potentially due to varying levels of capital intensity, technology transfer, or market dynamics within these industries.

Both tests largely confirm the presence of long-term relationships for aggregate lagged FDI, reinforcing its significance as a determinant of productivity. The disparity in Pedroni (1999, p. 653-670) test results across sectors indicates that the impact of FDI on productivity varies by industry, influenced by factors such as technology transfer, labor intensity, and market integration.

Once cointegration was confirmed, Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) are applied to estimate long-term coefficients. FMOLS corrects for issues like serial correlation and endogeneity in the presence of cointegrated variables, ensuring unbiased and efficient estimates. DOLS extends this by including leads and lags of the differenced explanatory variables to account for potential endogeneity and to improve efficiency.

[3] The Pesaran and Yamagata (2008) test was applied to each model, and in all cases, the null hypothesis (H_0) of slope homogeneity was found to be statistically significant and therefore accepted. Due to the large number of models, the detailed results have been omitted from the main reporting; however, they are available upon request.

Table 9: *Cointegration Test with Modified and Standard Test Results*

Model	Test Type*	Modified Test Stat.	p-value	Result	Test Stat.	p-value	Result
fdi_lag	Kao(ADF)	1.5512	0.0604	H0 rejected	3.7750	0.0001	H0 rejected
fdi_lag	Pedroni(PP)	5.2839	0.0000	H0 rejected	-2.9768	0.0015	H0 rejected
fdi_lag_CA	Kao (ADF)	1.5012	0.0667	H0 rejected	3.6256	0.0001	H0 rejected
fdi_lag_CA	Pedroni(PP)	1.6290	0.0517	H0 rejected	-0.7009	0.2417	H0 accepted
fdi_lag_CB	Kao (ADF)	1.4857	0.0687	H0 rejected	3.6353	0.0001	H0 rejected
fdi_lag_CB	Pedroni(PP)	1.3992	0.0809	H0 rejected	0.2736	0.3922	H0 accepted
fdi_lag_CC	Kao (ADF)	1.4857	0.0687	H0 rejected	3.6297	0.0001	H0 rejected
fdi_lag_CC	Pedroni(PP)	1.5914	0.0558	H0 rejected	0.6812	0.2479	H0 accepted
fdi_lag_CD	Kao (ADF)	1.4834	0.0690	H0 rejected	3.6266	0.0001	H0 rejected
fdi_lag_CD	Pedroni(PP)	0.0558	0.0463	H0 rejected	-12.4452	0.0000	H0 rejected
fdi_lag_CE	Kao (ADF)	1.5290	0.0631	H0 rejected	3.7263	0.0001	H0 rejected
fdi_lag_CE	Pedroni(PP)	1.7293	0.0419	H0 rejected	0.3398	0.3670	H0 accepted
fdi_lag_CF	Kao (ADF)	1.9883	0.0234	H0 rejected	3.8548	0.0001	H0 rejected
fdi_lag_CF	Pedroni(PP)	1.2068	0.1137	H0 accepted	-1.2168	0.1118	H0 accepted
fdi_lag_CG	Kao (ADF)	1.3617	0.0866	H0 rejected	3.5493	0.0002	H0 rejected
fdi_lag_CG	Pedroni(PP)	1.9297	0.0268	H0 rejected	1.7319	0.0416	H0 rejected
fdi_lag_CH	Kao (ADF)	1.4974	0.0671	H0 rejected	3.6321	0.0001	H0 rejected
fdi_lag_CH	Pedroni(PP)	2.0154	0.0219	H0 rejected	0.8330	0.2024	H0 accepted
fdi_lag_CI	Kao (ADF)	1.4828	0.0691	H0 rejected	3.6408	0.0001	H0 rejected
fdi_lag_CI	Pedroni(PP)	1.3784	0.0840	H0 rejected	-0.5825	0.2801	H0 accepted
fdi_lag_CJ	Kao (ADF)	1.4768	0.0699	H0 rejected	3.6308	0.0001	H0 rejected
fdi_lag_CJ	Pedroni(PP)	0.9955	0.1597	H0 accepted	-1.4437	0.0744	H0 rejected
fdi_lag_CK	Kao (ADF)	1.4664	0.0713	H0 rejected	3.6515	0.0001	H0 rejected
fdi_lag_CK	Pedroni(PP)	1.3037	0.0962	H0 rejected	-0.4397	0.3301	H0 accepted
fdi_lag_CL	Kao (ADF)	1.4804	0.0694	H0 rejected	3.5627	0.0002	H0 rejected
fdi_lag_CL	Pedroni(PP)	1.1032	0.1350	H0 accepted	-0.7513	0.2262	H0 accepted
fdi_lag_CM	Kao (ADF)	1.5017	0.0666	H0 rejected	3.6459	0.0001	H0 rejected
fdi_lag_CM	Pedroni(PP)	1.6303	0.0515	H0 rejected	0.8968	0.1849	H0 accepted
fdi_lag_CN	Kao (ADF)	1.4878	0.0684	H0 rejected	3.6245	0.0001	H0 rejected
fdi_lag_CN	Pedroni(PP)	1.4340	0.0758	H0 rejected	0.5927	0.2767	H0 accepted

***** ADF and PP denotes Augmented Dickey-Fuller Test and Phillips-Perron Tests, respectively.

Source: Own calculations.

These methods allow the capture of long-term dynamics that would otherwise be lost in short-term analysis.

Due to the limitation of panel estimation with sectoral interaction terms, it is not possible to implement Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) estimations to further elaborate the long term relationship at the sectoral level. However, it is possible to utilize the sectoral panels to examine the general relationship between manufacturing sector FDI(t-1) and sectoral productivity. Therefore, model in equation (12) is used for the analysis:

$$\boldsymbol{prod_{i,t}} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}\text{person\_cost\_pp}_{i,t} + \boldsymbol{\beta_2}\text{turnover\_in}_{i,t} + \boldsymbol{\beta_3}\text{ex\_im\_cov}_{i,t} + \boldsymbol{\beta_4}\text{purchase\_commercial}_{i,t} + \boldsymbol{\beta_5}\text{fdi}_{i,(t-1)} + \varepsilon_{i,t} \tag{12}$$

Estimation results of this model are illustrated in Table 10.

Table 10: *FMOLS and DOLS Estimation Results*

VARIABLES	(1) FMOLS	(2) DOLS
person_cost_pp	1.077*	1.075***
	(0.585)	(6.33e-09)
turnover_in	7.169***	18.90***
	(0.382)	(6.55e-10)
ex_im_cov	1,950***	-23,274***
	(714.0)	(0.000823)
purchase_commercial	2.48e-06***	2.32e-06***
	(6.11e-07)	(6.43e-07)
fdi_lag	0.0427**	1.677***
	(0.0171)	(9.14e-10)
linear	-77.83***	3,419***
	(29.32)	(9.50e-05)
Constant	41,567***	24,095***
	(772.8)	(0.000509)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Own calculations.

The FMOLS and DOLS estimations reveal long-term relationships between productivity and the explanatory variables, including lagged FDI. These results address potential challenges such as endogeneity and serial correlation, ensuring robust inferences in cointegrated panel models.

In the FMOLS results, personnel cost per person positively correlates with productivity, highlighting the crucial role of human capital in driving efficiency and output. This finding aligns with theoretical expectations, as investing in skilled labor enhances production capabilities and innovation. Similarly, the turnover index shows a positive relationship with productivity, suggesting that increased operational activity and market engagement contribute to productivity gains.

Export-import coverage also exhibits a positive correlation, indicating that a higher ratio of exports relative to imports promotes productivity. This could stem from enhanced competitiveness and greater integration into international markets, which foster learning-by-exporting effects. Additionally, the purchase of commercial products positively influences productivity, likely due to the complementary role of these goods in optimizing production processes. Finally, lagged FDI shows a positive and significant effect, reinforcing the idea that the benefits of FDI—such as technology transfer, managerial improvements, and market access—take time to materialize.

3.5 Autoregressive Distributed Lag (ARDL) Analysis

In the preliminary analysis, short-run dynamics were modeled with a random-effects model, while the long-run equilibrium was investigated using DOLS and FMOLS estimators. Notably, a long-run relationship was confirmed by the Kao cointegration test for lagged FDI however, such a relationship was not identified for its contemporaneous form. These findings therefore point to a complex dynamic that a simple two-step approach may not fully capture.

While valuable initial insights are provided by these methods, the ARDL framework is now employed to build upon these findings within a more integrated model. Through the utilization of the Panel ARDL approach, specifically the PMG estimator developed by Pesaran, Shin, and Smith (1999), both short-run dynamics and long-run equilibrium coefficients can be estimated simultaneously. This methodology is particularly advantageous as it provides robust estimates for variables with mixed orders of integration and can model heterogeneous short-run dynamics across different sectors, thus offering a more nuanced and unified analysis. Due to the short time dimension in the dataset, a maximum lag length was specified as 1 for the model to ensure sufficient degrees of freedom for robust estimation.

Long and short run analysis results are illustrated in Table 11 and Table 12, respectively:

Table 11: *ARDL Long Run Analysis Results*

Variable	Model a	Model b	Model c	Model d	Model e	Model f	Model g
ln_fdi_lag	Failed: Initial values not feasible	Failed: Hessian unstable	Failed: Hessian unstable	Failed: Hessian unstable	Failed: Initial values not feasible	0.107*** (0.032)	0.015** (0.007)
ln_person_cost_pp	Failed: Initial values not feasible	-	Failed: Hessian unstable	Failed: Hessian unstable	Failed: Initial values not feasible	1.548*** (0.209)	0.862*** (0.052)
turnover_in	Failed: Initial values not feasible	Failed: Hessian unstable	-	Failed: Hessian unstable	Failed: Initial values not feasible	-	0.001*** (0.000)
ln_purchase_commercial	Failed: Initial values not feasible	Failed: Hessian unstable	Failed: Hessian unstable	-	Failed: Initial values not feasible	-	-
ex_im_cov	Failed: Initial values not feasible	Failed: Hessian unstable	-	Failed: Hessian unstable	-	0.278*** (0.047)	-
Error Correction Term	Failed: Initial values not feasible	Failed: Hessian unstable	Failed: Hessian unstable	Failed: Hessian unstable	Failed: Initial values not feasible	-0.355*** (0.057)	-0.684*** (0.091)
Observations	161	161	161	161	161	161	161
Groups	14	14	14	14	14	14	14

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Own calculations.

The long-run results from the Panel ARDL analysis are presented for the two specifications that successfully converged, Model f and Model g. In Model f, the long-run coefficients for lagged FDI, human capital, and export-import coverage are all found to be positive and statistically significant at the 1% level. For Model g, the analysis shows that lagged FDI, personnel cost, and turnover index each have a positive and statistically significant long-run relationship with productivity. Crucially, both models feature a negative and highly significant error correction term (-0.355 in Model f and -0.684 in Model g), confirming the existence of a stable long-run cointegrating relationship among the variables.

Initial attempts to estimate more comprehensive specifications (Models a, b, c, d, e) were unsuccessful due to the short time dimension of the panel, which resulted in an insufficient number of observations and a lack of degrees of freedom for the individual cross-sections. Consequently, the analysis proceeded with two more parsimonious models that successfully converged: Model f and Model g. Of these, Model g is not only statistically superior but is also theoretically well-grounded. Its specification aligns with an augmented Solow growth framework, where fdi_lag serves as a proxy for capital accumulation and technological spillovers, ln_person_cost_pp represents investment in labor (human capital), and turnover_in captures the element of economic dynamism. We proceeded with the analysis of these available models.

The short-run dynamics, estimated individually for each sector, show considerable heterogeneity. The speed of adjustment back to long-run equilibrium is statistically significant in both models for a majority of the sectors. For instance, in Model g, the adjustment coefficient is negative and significant for 11 of the 14 sectors, including CA, CB, and CH. The short-run impact of changes in FDI is varied, with some sectors showing a significant positive effect (e.g., CB and CH) while others are insignificant. Similarly, the effect of a change in personnel costs is heterogeneous. In

Model g, turnover index is found to have a negative and statistically significant immediate impact on productivity in a large number of sectors.

Table 12: *ARDL Short Run Analysis Results*

Sector Code	Variable	Model f	Model g	Sector Code	Variable	Model f	Model g
CA	Speed of Adj.	-0.225 (0.208)	-0.845*** (0.256)	**CH**	Speed of Adj.	-0.271*** (0.082)	-0.819*** (0.152)
	D.ln_fdi_lag	0.011 (0.027)	0.027 (0.017)		D.ln_fdi_lag	0.077*** (0.021)	0.078*** (0.022)
	D.ln_person_cost_pp	-0.174 (0.404)	-0.199 (0.255)		D.ln_person_cost_pp	-0.421*** (0.150)	-0.391** (0.165)
	D.ex_im_cov	-0.179 (0.157)			D.ex_im_cov	-0.342*** (0.056)	
	D.turnover_in		-0.000* (0.000)		D.turnover_in		-0.001*** (0.000)
	_cons	-1.317 (1.279)	1.401** (0.622)		_cons	-1.495*** (0.518)	1.470*** (0.533)
CB	Speed of Adj.	-0.070 (0.044)	-0.646*** (0.167)	**CI**	Speed of Adj.	-0.451*** (0.161)	-0.978*** (0.255)
	D.ln_fdi_lag	0.153*** (0.025)	0.120*** (0.021)		D.ln_fdi_lag	0.002 (0.030)	0.057* (0.031)
	D.ln_person_cost_pp	0.460*** (0.115)	0.035 (0.136)		D.ln_person_cost_pp	-0.203 (0.297)	-0.528* (0.308)
	D.ex_im_cov	-0.029 (0.022)			D.ex_im_cov	-0.218*** (0.057)	
	D.turnover_in		-0.000*** (0.000)		D.turnover_in		-0.001*** (0.000)
	_cons	-0.411 (0.285)	1.049** (0.459)		_cons	-2.578** (1.205)	1.792*** (0.687)
CC	Speed of Adj.	-0.186*** (0.054)	-0.561*** (0.182)	**CJ**	Speed of Adj.	-0.263*** (0.089)	-1.104*** (0.205)
	D.ln_fdi_lag	-0.020* (0.012)	-0.001 (0.012)		D.ln_fdi_lag	0.043 (0.054)	0.009 (0.037)
	D.ln_person_cost_pp	0.613*** (0.102)	0.192 (0.174)		D.ln_person_cost_pp	-0.393 (0.287)	-1.021*** (0.246)
	D.ex_im_cov	-0.256*** (0.044)			D.ex_im_cov	-0.134 (0.086)	
	D.turnover_in		0.000 (0.000)		D.turnover_in		-0.001*** (0.000)
	_cons	-0.902*** (0.301)	0.860* (0.439)		_cons	-1.342** (0.591)	2.035*** (0.636)
CD	Speed of Adj.	0.207** (0.087)	-0.493 (0.406)	**CK**	Speed of Adj.	-0.226* (0.117)	-1.270*** (0.281)
	D.ln_fdi_lag	-0.019 (0.018)	0.177*** (0.059)		D.ln_fdi_lag	0.007 (0.019)	-0.007 (0.017)
	D.ln_person_cost_pp	1.030*** (0.131)	0.284 (0.411)		D.ln_person_cost_pp	-1.707*** (0.428)	-0.798*** (0.299)
	D.ex_im_cov	0.460*** (0.080)			D.ex_im_cov	-1.184*** (0.306)	
	D.turnover_in		0.000 (0.000)		D.turnover_in		-0.001*** (0.000)
	_cons	1.022*** (0.382)	0.905 (0.840)		_cons	-1.063 (0.774)	2.273*** (0.858)
CE	Speed of Adj.	-0.329*** (0.074)	-0.581*** (0.107)	**CL**	Speed of Adj.	-0.142 (0.140)	-0.704** (0.357)
	D.ln_fdi_lag	0.022 (0.024)	0.047** (0.018)		D.ln_fdi_lag	0.076 (0.056)	0.036 (0.056)
	D.ln_person_cost_pp	-0.455*** (0.146)	-0.509*** (0.152)		D.ln_person_cost_pp	-0.142 (0.584)	-0.662 (0.593)
	D.ex_im_cov	-0.535* (0.273)			D.ex_im_cov	-0.091 (0.322)	
	D.turnover_in		-0.000*** (0.000)		D.turnover_in		-0.000 (0.000)
	_cons	-1.682** (0.759)	1.115*** (0.372)		_cons	-0.778 (0.828)	1.346* (0.793)
CF	Speed of Adj.	-0.110 (0.706)	-0.921** (0.409)	**CM**	Speed of Adj.	0.004 (0.108)	-0.137 (0.268)
	D.ln_fdi_lag	-4.600 (5.107)	-1.050 (5.997)		D.ln_fdi_lag	0.127*** (0.046)	0.109** (0.053)
	D.ln_person_cost_pp	1.338 (1.093)	0.099 (0.294)		D.ln_person_cost_pp	0.196 (0.381)	0.022 (0.495)
	D.ex_im_cov	80.741* (48.057)			D.ex_im_cov	-0.003 (0.077)	
	D.turnover_in		-0.002 (0.004)		D.turnover_in		0.000 (0.000)
	_cons	-1.176 (3.821)	0.160 (2.193)		_cons	0.070 (0.644)	0.306 (0.533)
CG	Speed of Adj.	0.043 (0.094)	0.089 (0.130)	**CN**	Speed of Adj.	-0.355*** (0.078)	-1.071*** (0.137)
	D.ln_fdi_lag	0.084 (0.064)	0.063 (0.064)		D.ln_fdi_lag	0.041*** (0.010)	0.043*** (0.009)
	D.ln_person_cost_pp	0.802** (0.367)	0.447 (0.323)		D.ln_person_cost_pp	-0.192 (0.140)	-0.581*** (0.122)
	D.ex_im_cov	-1.168 (0.964)			D.ex_im_cov	-0.247*** (0.042)	
	D.turnover_in		-0.000 (0.000)		D.turnover_in		-0.001*** (0.000)
	_cons	0.299 (0.529)	-0.142 (0.295)		_cons	-2.063*** (0.672)	1.488** (0.611)

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Own calculations.

A comparative analysis of the short-run dynamics reveals that substituting turnover index for export-import coverage fundamentally improves the model, making Model g vastly superior to Model f. The most critical improvement is seen in the speed of adjustment coefficient, which becomes negative and highly significant across most sectors in Model g. This confirms a valid error correction mechanism that was largely absent or theoretically inconsistent in Model f.

Furthermore, the inclusion of turnover index clarifies the effects of the other variables. In Model g, the short-run impact of FDI becomes more consistently positive and significant, while the effect of personnel costs consolidates into a more coherent negative relationship. The turnover index variable itself is a powerful and systematic predictor of short-run dynamics, in sharp contrast to the inconsistent results for export-import coverage. This comparative analysis strongly suggests that including firm dynamism is crucial for a well-specified model, yielding more reliable and theoretically sound estimates.

3.6 General Remarks on the Results

A comparison of the short-term estimates from the Random Effects models and the more advanced Panel ARDL models reveals several key similarities, suggesting a degree of robustness to the findings. The most notable consistency is found for the turnover index. The Random Effects models consistently find a negative and highly statistically significant short-run impact of firm turnover on productivity. This finding is strongly mirrored in the Panel ARDL results (Model g), where the coefficient for turnover index is also negative and significant for the vast majority of individual sectors. This alignment across different methodologies provides strong evidence for a genuine, negative short-run relationship.

Similarly, both analyses suggest that the short-run effect of FDI is not uniform across all sectors. The Random Effects models, through the use of interaction terms, show that the FDI effect varies significantly by sector. This conclusion of heterogeneity is the very foundation of the Panel ARDL short-run results, which also show a mix of positive, significant effects in some sectors and insignificant effects in others.

Building on the robust finding of heterogeneity, a deeper investigation into the economic reasons for these divergent sectoral responses is warranted. The detailed short-run estimates from the Panel ARDL model allow for a nuanced analysis of why some industries benefit immediately from foreign investment while others do not. The sectors can be broadly categorized into two distinct groups based on their short-run productivity response to FDI:

1. High-Spillover Sectors: This group includes seven industries where FDI has a statistically significant and positive short-run impact: Textiles and Apparel (CB), Wood Products (CD), Paper and Printing (CE), Rubber and Plastic Products (CH), Other Non-Metallic Mineral Products (CI), Transportation Equipment (CM), and Furniture (CN). The immediate productivity gains in these sectors can be attributed to several factors. Many of these industries benefit from efficiency-seeking FDI that introduces advanced technology and managerial practices. A particularly interesting dynamic is observed within this group; several sectors (such as CH, CI, and CN) simultaneously exhibit a significant negative short-run coefficient for human capital costs. This suggests a complex "adjustment friction," where the immediate costs of higher wages or hiring more skilled labor are not instantly offset by productivity gains, even while the benefits from foreign capital itself are realized.

2. Insignificant-Effect Sectors: The second group, containing the remaining seven sectors, shows no statistically significant short-run productivity response to FDI. This group includes large traditional industries like Food and Beverages (CA) and capital-intensive ones such as Chemicals (CG) and Basic Metals (CJ). The lack of an immediate effect does not mean FDI is unhelpful, but rather that its benefits likely require a longer gestation period. This could be due to the 'nature of FDI' in these sectors being more market-seeking, or because 'structural factors'—such as intense domestic competition based on cost rather than technology, or skills mismatches—slow the absorption of spillovers. For these industries, the positive long-run effect of FDI found in our analysis is paramount, as it confirms that the benefits, while not immediate, do eventually materialize.

For the human capital variable (proxied by person_cost_pp), the Random Effects model points toward a uniformly positive and significant short-run effect. While the Panel ARDL analysis shows more complexity with mixed results across sectors, its findings for several key sectors (such as CB, CC, CD, and CG) are consistent with the positive sign found in the simpler model. Despite the methodological differences, the initial short-term analysis is broadly similar to the ARDL results in two crucial ways: it correctly identifies the consistent, negative short-run impact of firm dynamism and captures the heterogeneous nature of the FDI effect.

To ensure the robustness of the findings, the long-run determinants of productivity were analyzed using three distinct panel cointegration techniques: FMOLS, DOLS and PMG estimator for the Panel ARDL model. A comparative analysis reveals a high degree of consistency across these methods for the core variables, strengthening confidence in the overall conclusions.

The positive and statistically significant long-run effect of human capital on productivity is a consistent finding across all estimations. The FMOLS and DOLS models both find a significant positive relationship, a result strongly corroborated by the Panel ARDL estimates. This uniformity underscores the fundamental role of investment in higher-skilled, higher-paid labor as a primary driver of long-term productivity gains.

Similarly, the impact of lagged FDI is consistently positive and significant in the long run across the FMOLS, DOLS, and Panel ARDL models. This contrasts with its insignificance in simpler short-term models, underscoring the delayed benefits of FDI. This robust long-run finding supports the hypothesis that the productivity-enhancing effects of foreign investment, likely through technology spillovers and capital deepening, manifest over an extended period.

A particularly interesting dynamic is observed for the turnover index. While initial short-term models show a negative relationship, suggesting adjustment costs or inefficiencies, the long-term perspective is consistently positive. Both the FMOLS and DOLS estimations find a significant positive long-run correlation, and this dual nature is perfectly captured within the Panel ARDL framework. The ARDL model not only confirms a positive and significant long-run coefficient for turnover but also reveals a negative effect in its short-run dynamics, elegantly modelling how initial disruptions transition into long-term efficiency gains.

The impact of export-import coverage presents a more complex picture, with divergent results. The FMOLS estimation finds a positive and significant relationship, suggesting that export competitiveness bolsters productivity. Notably, the Panel ARDL estimation aligns with this positive finding, providing additional corroboration. In contrast, the DOLS model returns a negative coefficient, which may point to short-term challenges like resource constraints or over-dependence on specific export markets. This divergence highlights the multifaceted nature of trade's impact, which likely depends on sectoral characteristics and global conditions, though the weight of the evidence from two of the three advanced methods points toward a positive long-run relationship.

The use of multiple robust estimators confirms the long-term productivity-enhancing roles of human capital, lagged FDI, and firm dynamism. The Panel ARDL model, in particular, proves invaluable by not only supporting the long-run findings of FMOLS and DOLS but also by simultaneously modelling the short-run dynamics that explain the transition to this long-run equilibrium.

4. Conclusion

This study provides a comprehensive analysis of the relationship between FDI and productivity in Türkiye’s manufacturing industry in general and sectoral levels for the period of 2009-2022, by employing a multi-stage approach that considers both static short-term correlations and a fully integrated dynamic framework. The findings underscore the multifaceted and sector-specific dynamics of FDI’s impact, reflecting the complexity of interactions between foreign investments and domestic economic structures.

In the short term, the results highlight the significant roles of personnel cost per person and the turnover index in influencing productivity. While human capital investments positively enhance productivity, high workforce turnover negatively affects production efficiency. The export-import coverage ratio and the purchase of commercial goods, however, show limited direct influence on productivity within this timeframe. Current FDI inflows exhibit positive effects overall, with sectoral variations revealing both beneficial spillovers in some industries and negative crowding-out effects in others. These mixed results emphasize the importance of aligning FDI with domestic absorptive capacities and sectoral priorities. The Panel ARDL estimation provides further detail on these short-run dynamics, confirming significant heterogeneity. Its results identify a statistically significant positive FDI effect in seven of the fourteen sectors, while the effect in the remaining sectors is found to be insignificant.

The analysis of lagged FDI inflows provides deeper insights into the dynamic nature of FDI’s impact. While the aggregate lagged FDI variable appears insignificant in the short term, sectoral-level estimations reveal significant and diverse effects. Some sectors benefit from delayed productivity gains due to technology transfer and capacity-building processes, while others face challenges such as adjustment costs or diminishing returns. The contrasting effects across sectors underscore the need for targeted policies that account for industry-specific characteristics.

In the long-term estimations, the significance of lagged FDI becomes evident, reinforcing its role as a critical determinant of productivity. The findings from FMOLS and DOLS estimations highlight the positive contributions of human capital, turnover index, export-import coverage, and the purchase of commercial goods to productivity. However, the contrasting results for export-import coverage between FMOLS and DOLS reflect the complex interplay between trade dynamics and productivity, suggesting the need for balanced trade policies. The persistent positive relationship between lagged FDI and productivity underscores the long-term benefits of sustained foreign investment, particularly in technologically advanced and capital-intensive sectors. This long-run positive relationship is further corroborated by the Panel ARDL estimation, which also yields a positive and statistically significant coefficient for lagged FDI. Furthermore, the ARDL model identifies a significant error correction term, indicating the existence of a stable cointegrating relationship and quantifying the speed of adjustment back to equilibrium after a shock.

The comparison between short-term and long-term results reveals important differences in how FDI influences productivity. In the short-term models, the export-import coverage ratio and the purchase of commercial goods are found to be insignificant, suggesting that their effects may require time to manifest. Similarly, lagged FDI inflows show no significant immediate impact but exhibit strong positive effects in the long-term estimations. This highlights the delayed nature of benefits such as technology absorption, capacity building, and market integration. Interestingly, the turnover index transitions from a negative effect in the short term to a positive relationship in the long term, suggesting that initial inefficiencies or adjustment costs diminish over time, eventually contributing to productivity gains. The Panel ARDL framework explicitly captures this dynamic, simultaneously estimating negative short-run coefficients and a positive long-run coefficient for the turnover index within a single integrated model.

From a policy perspective, the study emphasizes that strategies must move beyond simply attracting FDI and towards creating an environment that maximizes its long-term benefits. The evidence of significant short-run heterogeneity, in particular, allows for the formulation of targeted, evidence-based strategies that move beyond a uniform approach. For sectors identified as 'High-Spillover,' where FDI already generates immediate productivity gains, policy can be geared towards reducing administrative barriers and streamlining investment to capitalize on existing strengths. Conversely, for sectors where the immediate effect is insignificant, a foundational approach is required; here, strategic policy should prioritize enhancing domestic 'absorptive capacity' by supporting workforce training and local technology adoption. This entire strategy must be underpinned by the most robust finding across all models: the powerful and significant impact of human capital. This suggests that a consistent and long-term commitment to enhancing the skill level of the domestic workforce is the most reliable pathway to ensure that FDI translates into sustained productivity growth. Additionally, to support these efforts, trade policies should strike a balance between fostering export competitiveness and ensuring access to critical imports.

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APPENDIX

Table A: *Results of Cross Section Dependency Test by Pesaran (2004)*

Variable	Pesaran CD Test p-value	Hypothesis* Result	Variable	Pesaran CD Test p-value	Hypothesis Result	Variable	Pesaran CD Test p-value	Hypothesis Result
fdi	0.3564	H0 accepted	**fdi_CL**	0.2215	H0 accepted	**fdi_lag_CJ**	0.4205	H0 accepted
fdi_CA	0.5381	H0 accepted	**fdi_CM**	0.5646	H0 accepted	**fdi_lag_CK**	0.5179	H0 accepted
fdi_CB	0.2265	H0 accepted	**fdi_lag**	0.5229	H0 accepted	**fdi_lag_CL**	0.3184	H0 accepted
fdi_CC	0.4240	H0 accepted	**fdi_lag_CA**	0.5819	H0 accepted	**fdi_lag_CM**	0.2784	H0 accepted
fdi_CD	0.4728	H0 accepted	**fdi_lag_CB**	0.7207	H0 accepted	**fdi_lag_CN**	0.5808	H0 accepted
fdi_CE	0.3217	H0 accepted	**fdi_lag_CC**	0.5029	H0 accepted	**prod**	0.7268	H0 accepted
fdi_CF	0.3020	H0 accepted	**fdi_lag_CD**	0.4366	H0 accepted	**person _cost_pp**	0.6744	H0 accepted
fdi_CG	0.3145	H0 accepted	**fdi_lag_CE**	0.4026	H0 accepted	**turnover_in**	0.4095	H0 accepted
fdi_CH	0.5028	H0 accepted	**fdi_lag_CF**	0.5953	H0 accepted	**ex_im_cov**	0.4061	H0 accepted
fdi_CI	0.3738	H0 accepted	**fdi_lag_CG**	0.3263	H0 accepted	**purchase _commercial**	0.5198	H0 accepted
fdi_CJ	0.5026	H0 accepted	**fdi_lag_CH**	0.5938	H0 accepted			
fdi_CK	0.2820	H0 accepted	**fdi_lag_CI**	0.3239	H0 accepted			

Source: Own calculations.