Determinants of Total Factor Productivity (TFP) in Rich Natural Resource Countries: Application to Saudi Arabia Using the Panel ARDL Model

Ahmed Badawi , Anas Al Qudah * , Ahmed Alwaked

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Article

Determinants of Total Factor Productivity (TFP) in Rich Natural Resource Countries: Application to Saudi Arabia Using the Panel ARDL Model

Ahmed Badawi [1], **Anas Al Qudah** [2,*] **and Ahmed Alwaked** [3]

[1] Saudi Industrial development Fund, Riyadh, Saudi Arabia
[2] Banking and Finance Depaertment, Yarmouk University, Jordan
[3] Economics Depaertment, Yarmouk University , Jordan
* Correspondence: anas.qudah@yu.edu.jo

Abstract

This study examines the determinants of Total Factor Productivity (TFP) across 24 manufacturing sectors in Saudi Arabia from 2005 to 2021, employing the Pooled Mean Group (PMG) estimation within a panel ARDL framework. The findings reveal that, in the long run, foreign direct investment (FDI), human capital development, credit to the manufacturing sector, and trade openness significantly enhance TFP. Conversely, inflation and heavy reliance on imported information and communication technology (ICT) goods exert a negative impact. In the short run, however, only FDI and trade openness show significant effects, with FDI initially exerting a negative influence that reverses to a positive one over time. These results underscore the crucial role of long-term strategies that focus on investment, human capital development, financial sector growth, and trade policies in fostering productivity growth. The sector-level results provide policymakers with actionable insights to design targeted interventions that support Saudi Arabia's industrial transformation goals.

Keywords: total factor productivity; Saudi Arabia; Panel ARDL; manufacturing sector; economic growth

1. Introduction

Total Factor Productivity (TFP) lies at the heart of modern growth theories, particularly those emphasizing the endogenous drivers of technological progress. Endogenous growth models, such as those proposed by Lucas Jr (1988); (Romer, 1986), posit that investments in human capital, innovation, and knowledge accumulation sustain long-term economic growth without diminishing returns to capital. In these frameworks, productivity improvements arise internally through purposeful economic activity rather than an unexplained external force.

A substantial body of empirical research underscores the essential role of factors such as education, research and development (R&D), financial development, and international trade in shaping TFP dynamics. In particular, investments in information and communication technology (ICT), foreign direct investment (FDI), and open trade policies have been recognized as key channels for technological diffusion and efficiency gains across sectors.

Saudi Arabia presents a unique case for investigating TFP determinants within this theoretical and empirical context. As a resource-rich economy with a strategic vision to diversify beyond oil dependence, the Kingdom has articulated ambitious industrialization goals through its National Industrial Strategy (2022). This strategy aims to enhance the industrial sector's contribution to GDP, boost non-oil exports, create high-value job opportunities, and attract quality investments.

Despite abundant natural resources, sustainable productivity growth remains a significant policy challenge. While resource abundance can provide substantial revenues, it can also hinder productivity without strategic investments in human capital, technology, and innovation. Therefore,

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understanding the sector-specific drivers of TFP within the Saudi manufacturing sector is essential for designing effective policies that support the broader transformation agenda.

This study aims to fill this gap by identifying the key determinants of TFP across 24 manufacturing sectors in Saudi Arabia from 2005 to 2021. Using a panel ARDL modeling approach, we seek to answer the following research questions:

- What are the main long-run and short-run drivers of sectoral TFP in Saudi Arabia?
- How do these determinants align with or differ from international evidence?
- What implications do these findings have for industrial policy in a resource-rich economy?

The remainder of this paper is structured as follows: Section 2 reviews the relevant literature on TFP determinants. Section 3 describes the methodology for estimating TFP at the sectoral level. Section 4 outlines the empirical model and variable construction. Section 5 presents and discusses the econometric results. Finally, Section 6 concludes with policy recommendations.

2. Literature Review

The determinants of Total Factor Productivity (TFP) have been extensively studied across different levels of analysis, from country-level to firm-level dynamics. A broad consensus within endogenous growth theory underscores the importance of internal drivers such as human capital, innovation, and technological diffusion in sustaining productivity growth (Al-qalawi et al., 2025; Lucas Jr, 1988; Romer, 1986).

Human Capital and Innovation:

Numerous studies have highlighted the pivotal role of education and R&D investment in enhancing TFP. Danquah et al. (2011) found that initial GDP, human capital, and consumption share significantly influence TFP growth across countries. Similarly, Constantinos (2019) emphasized that R&D and human capital exert a robust positive impact on TFP within OECD countries, often outweighing the contribution of FDI. Firm-level evidence also corroborates these findings; for instance, Gornig and Schiersch (2024) demonstrated that localization economies and R&D intensity positively correlate with firm-level TFP.

Trade Openness, FDI, and Technology Transfers:

Trade openness and foreign direct investment (FDI) are widely recognized as critical channels for technological spillovers. Arizala et al. (2013) found that financial development and openness significantly enhance industry-level TFP. Augier et al. (2013) demonstrated that firms sourcing intermediate goods internationally improve their TFP, contingent on their absorptive capacity. In the context of emerging economies, Tsamadias et al. (2019) observed that trade openness and FDI positively affect TFP, although with stronger impacts in non-European countries.

Financial Development and Credit Access:

Access to finance plays a vital role in enabling firms to adopt new technologies and expand productive capacities. Malik et al. (2021) showed that financial development significantly boosts TFP in India, with capital formation and credit availability acting as enablers of productivity gains. Everaert et al. (2015) further suggested that fiscal policies supporting productive investments, as opposed to social transfers, enhance TFP across OECD countries.

Inflation and Macroeconomic Stability:

Macroeconomic stability, particularly low and stable inflation, is frequently associated with higher productivity growth. Fischer (1993) emphasized that inflation impedes investment and productivity by increasing uncertainty and transaction costs. More recent findings by Malik et al.

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(2021) confirm that persistent inflation negatively correlates with TFP performance, particularly in emerging economies.

Natural Resource Abundance and Institutional Quality:

Several studies have explored the "resource curse" hypothesis, which posits that abundant natural resources can hinder productivity growth absent strong institutions. Cuevas Ahumada and Calderón Villarreal (2022) demonstrated that oil rents negatively affect TFP, but sound institutional frameworks can mitigate this effect. Their findings are particularly relevant for resource-rich countries like Saudi Arabia, aiming to diversify economic growth.

Firm-Level Determinants and Sectoral Dynamics:

Firm-specific factors such as firm size, age, export orientation, and management quality have also been found to influence TFP. Linh (2021) summarized the micro-level determinants of TFP, emphasizing the critical role of internal capabilities alongside external conditions. Sector-specific studies, such as Roszko-Wójtowicz et al. (2019) for Polish manufacturing sectors, underscore the heterogeneity of TFP dynamics depending on industry characteristics and R&D intensity.

Research Gap and Contribution:

While substantial evidence exists regarding the macro and micro determinants of TFP, relatively few studies have systematically examined the sector-level TFP determinants within resource-rich economies like Saudi Arabia. Moreover, the interaction between imported technology, credit allocation, and human capital accumulation remains underexplored in this context. By applying a panel ARDL model across 24 manufacturing sectors in Saudi Arabia from 2005 to 2021, this study aims to bridge these gaps and provide sector-specific insights that can inform industrial policy within the Kingdom's ongoing economic diversification efforts.

3. TFP Estimation

Reliable estimation of Total Factor Productivity (TFP) is essential for analyzing sector-level productivity dynamics. This study adopts a production function approach based on the Cobb-Douglas specification, utilizing sectoral data from Saudi Arabia's manufacturing sector between 2005 and 2021. Following standard practices in the literature, we construct sector-specific measures of capital stock, labor input, and output to compute the Solow residual as a proxy for TFP.

Capital Stock Estimation (K) :

Since direct observations of capital stock are typically unavailable, we estimate sectoral capital stocks using the perpetual inventory method (PIM), in line with the approach employed by the Penn World Table (PWT) (Inklaar et al., 2019). The capital stock at time *t* for sector *i* is calculated as:

$K_{ti} = (1 - \delta) K_{t-1i} + I_{ti}$ ……. (1)

Where K_{ti} is capital stock at time t for sector i , δ represents the average depreciation rate, and I_{ti} denotes gross capital formation at time t for sector $_i$.

To address the initial capital stock value K_{1i}, we assume a steady-state condition based on the Solow model:

$K_{1i} = I_{1i} / g + \delta$ ……. (2)

Where g is the average private investment growth rate before the sample period, estimated at 4.5% based on national accounts data for 1999–2003, and δ is set at 7.5% following Saudi accounting standards. Table 1 shows the calculation process of capital stock for the economic sectors.

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Table 1. Capital Stock Calculations.

Sectors	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
10 - Manufacture of food products	48053.02	51612.15	56228.22	61100.68	64875.84	68414.76	71638.33	75217.9	79208.66	79472.78	79889.91	79855.65	79759.82	77915.13	77663.92	76437.24	76112.98
11 - Manufacture of beverages	3632.039	3901.052	4249.954	4618.234	4903.575	5171.061	5433.469	5729.156	6234.104	7163.362	7914.803	8498.815	9187.037	9396.509	9881.8	10147.62	10556.81
12 - Manufacture of tobacco products	3.951521	4.244197	4.623788	5.024462	5.334903	5.625918	5.891402	6.199682	6.584064	8.787075	10.82201	12.46751	14.03545	14.69958	15.92987	16.66196	17.66524
13 - Manufacture of textiles	10380.41	11149.25	12146.41	13198.96	14014.47	14778.95	15528.91	16355.02	17246.55	17083.1	17031.45	16857.96	16927.62	16667.08	16636.02	16452.16	16481.51
14 - Manufacture of wearing apparel	7354.982	7899.74	8606.275	9352.053	9929.877	10471.54	10964.94	11512.83	12510.29	12496.16	12816.59	13011.43	13317.46	13253.18	13445.7	13446.96	13631.02
15 - Manufacture of leather and related products	6661.092	7154.457	7794.335	8469.754	8993.065	9483.629	9923.601	10408.15	10796.69	10153.69	9573.992	9020.735	8508.056	8112.405	7717.543	7334.166	7049.007
16 - Manufacture of wood and of products of wood and cork	8598.742	9235.622	10061.64	10933.53	11609.06	12242.33	12863.57	13563.6	14446.32	14200.45	13989.94	13708.7	13613.19	13218.83	13042.32	12765.83	12620.29
17 - Manufacture of paper and paper products	17080.93	18346.06	19986.89	21718.85	23060.77	24318.71	25493.97	26826.55	28588.79	27422.62	26403.47	25354.91	24452.49	23647.12	22945.88	22173.22	21713.05
18 - Printing and reproduction of recorded media	5766.094	6193.169	6747.072	7331.74	7784.738	8209.389	8616.051	9075.684	9669.093	9700.52	9961.204	10081.69	10272.7	10453.94	10670.56	10755.79	11066.65
19 - Manufacture of coke and refined petroleum products	16547.92	17773.56	19363.19	21041.11	22341.15	23559.85	24698.43	25959.2	31863.41	37753.67	43612.29	48159.81	54220.86	83190.36	97506.84	111549.2	135457.4
20 - Manufacture of chemicals and chemical products	92795.04	99668.05	108582.1	117991.3	125281.5	132115.5	138340.6	145253	153308.6	192950.1	226110.6	252664.1	267626.7	280978.9	299513	309197.8	326770.4
21 - Manufacture of products and preparations pharmaceutical	642.8485	690.4621	752.2154	817.3987	867.9024	915.2458	957.7063	1004.47	1071.179	1343.24	1606.491	1823.126	2073.18	2177.609	2358.362	2473.689	2626.904
22 - Manufacture of rubber and plastics products	14535.13	15611.7	17007.98	18481.8	19623.72	20694.18	21744.31	22927.62	24419.76	23158.67	22264.26	21379.01	20669.05	19717.71	19034.88	18281.78	17692.35
23 - Manufacture of other non-metallic mineral products	37036.96	39780.16	43338.01	47093.47	50003.18	52730.81	74278.51	75810.68	74305.6	86057.44	97525.75	106301.5	117698.2	122176.9	130117.3	135095.1	142102.3
24 - Manufacture of basic metals	9799.819	10525.66	11467.05	12460.73	13230.62	13952.34	14626.62	15391.16	16239.87	15520.75	14905.25	14288.68	13759.87	13635.94	13354.16	13052.88	13041.02
25 - Manufacture of fabricated metal products	23731.01	25488.69	27768.34	30174.6	32038.97	33786.67	35501.18	37476.48	40367.64	38423.06	36658.04	34921.27	33474.01	31809.1	30489.61	29118.49	28012.27
26 - Manufacture of computer, electronic and optical products	525.08	563.9709	614.4112	667.653	708.9045	747.5747	782.7986	821.9132	1008.385	1135.252	1436.796	1683.324	1958.295	2083.536	2286.828	2420.039	2592.655
27 - Manufacture of electrical equipment	27794.15	29852.77	32522.74	35341	37524.57	39571.51	41579.57	43842.31	46695.58	43989.5	41498.4	39108.04	36994.59	35365.06	33716.45	32122.88	30966.85
28 - Manufacture of machinery and equipment n.e.c.	20117.03	21607.03	23539.52	25579.33	27159.77	28641.32	29990.84	31526.14	33983.94	32081.99	30478.72	28911.03	27559.1	26104.13	24903.75	23686.77	22662.95
29 - Manufacture of motor vehicles, trailers and semi-trailers	2278.479	2447.238	2666.114	2897.146	3076.149	3243.95	3400.72	3578.477	3866.385	3875.773	4122.812	4311.57	4548.504	4596.656	4759.329	4833.055	4973.798
30 - Manufacture of other transport equipment	898.8903	965.468	1051.817	1142.963	1213.582	1279.781	1339.154	1404.542	1629.914	1950.752	2432.229	2834.911	3271.644	3764.542	4204.361	4541.076	5042.803
31 - Manufacture of furniture	16679.09	17914.45	19516.68	21207.9	22518.25	23746.6	24951.63	26309.48	28021.71	27736.31	27626.74	27337.67	27326.98	26646.93	26463.97	26019.76	25854.08
32 - Other manufacturing	1189.157	1277.233	1391.466	1512.044	1605.467	1693.044	1776.911	1871.703	2522.455	2663.538	2802.221	2896.312	3013.694	3033.09	3116.813	3147.553	3224.384
33 - Repair and installation of machinery and equipment	3704.984	3979.4	4335.308	4710.985	5002.057	5274.915	5542.593	5850.986	6627.1	10547.78	14013.15	16542.15	19125.34	20462.96	22503.44	23827.55	25597.92
capital stock in Mn SAR	**375807**	**403642**	**439742**	**477848**	**507373**	**535049**	**579980**	**607723**	**644639**	**696889**	**744686**	**779565**	**809372**	**848422**	**886349**	**908897**	**955887**

Source: Authors' calculations based on the collected dataset.

Labor Input Estimation ***(L)*** *:*

Labor input for each manufacturing subsector was derived from the employment data of the General Authority for Statistics (GASTAT). Total labor force data were disaggregated into ISIC-4 two-digit subsectors based on the Business Establishments Survey for the corresponding years. We utilize 24 sectors, including oil sectors, following the ISIC 4 – 2 digits classification. Table 2 displays the manufacturing sectors (ISIC 4 – 2 digits), while Table 3 illustrates the labor count for Saudi manufacturing.

Table 2. – Manufacturing sectors (ISIC 4 – 2 digits).

Sectors
10 - Manufacture of food products
11 - Manufacture of beverages
12 - Manufacture of tobacco products
13 - Manufacture of textiles
14 - Manufacture of wearing apparel
15 - Manufacture of leather and related products
16 - Manufacture of wood and of products of wood and cork
17 - Manufacture of paper and paper products
18 - Printing and reproduction of recorded media
19 - Manufacture of coke and refined petroleum products
20 - Manufacture of chemicals and chemical products

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21 - Manufacture of products and preparations pharmaceutical
22 - Manufacture of rubber and plastics products
23 - Manufacture of other non-metallic mineral products
24 - Manufacture of basic metals
25 - Manufacture of fabricated metal products
26 - Manufacture of computer, electronic and optical products
27 - Manufacture of electrical equipment
28 - Manufacture of machinery and equipment n.e.c.
29 - Manufacture of motor vehicles, trailers and semi-trailers
30 - Manufacture of other transport equipment
31 - Manufacture of furniture
32 - Other manufacturing
33 - Repair and installation of machinery and equipment

Source: Authors' calculations based on the collected dataset.

Table 3. – labor count for Saudi manufacturing sectors in thousands (2005-2021).

Sectors	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
10 - Manufacture of food products	59.74549	73.00851	74.82952	71.96278	78.79972	90.15524	105.7346	105.7776	74.1792	108.617	122.7004	103.3784	101.776	83.95082	77.67005	74.01456	83.18984
11 - Manufacture of beverages	15.36711	18.77849	19.24687	18.50952	20.26804	23.18879	27.19594	27.207	19.0796	27.93732	32.14587	26.92856	26.58585	21.84568	20.21124	19.26001	21.64759
12 - Manufacture of tobacco products	0.118209	0.14445	0.148053	0.142381	0.155908	0.178375	0.2092	0.209285	0.146766	0.214902	0.245781	0.207611	0.227925	0.172709	0.159785	0.152265	0.17114
13 - Manufacture of textiles	11.88659	14.52532	14.88762	14.31727	15.6775	17.93673	21.03629	21.04485	14.75823	21.60975	24.85959	20.79711	20.46764	16.87038	15.60819	14.8736	16.71742
14 - Manufacture of wearing apparel	43.80521	53.52961	54.86477	52.76289	57.77571	66.10155	77.52425	77.55579	54.38796	79.63762	90.40816	76.43969	74.9479	61.82584	57.20029	54.5082	61.26536
15 - Manufacture of leather and related products	1.180932	1.44309	1.479084	1.42242	1.557559	1.782013	2.089955	2.090805	1.46623	2.146928	2.448868	2.029054	2.007525	1.65963	1.535466	1.4632	1.644587
16 - Manufacture of wood and of products of wood and cork	15.24602	18.63051	19.09521	18.36366	20.10833	23.00607	26.98164	26.99262	18.92926	27.71718	31.24318	26.23468	25.6813	21.3219	19.72675	18.79832	21.12867
17 - Manufacture of paper and paper products	8.995961	10.99299	11.26718	10.83553	11.86498	13.5748	15.9206	15.92707	11.16926	16.3546	18.6257	15.59391	15.42291	12.69223	11.74265	11.18999	12.57717
18 - Printing and reproduction of recorded media	9.946819	12.15493	12.45811	11.98083	13.11909	15.00963	17.60338	17.61054	12.34984	18.08326	20.47687	17.38859	17.20161	14.07402	13.02103	12.40821	13.9464
19 - Manufacture of coke and refined petroleum products	9.469948	11.5722	11.86084	11.40645	12.49013	14.29004	16.75944	16.76625	11.75776	17.21631	20.50257	17.32493	17.52428	21.29521	12.91874	12.31073	13.83684
20 - Manufacture of chemicals and chemical products	50.61518	61.85134	63.39406	60.96541	66.75754	76.37771	89.57619	89.61262	62.84313	92.01809	105.5672	89.28482	87.27282	71.9594	66.57559	63.44225	71.30692
21 - Manufacture of products and preparations pharmaceutical	3.789594	4.630853	4.746358	4.564523	4.998183	5.718452	6.706632	6.70936	4.705109	6.889459	7.936479	6.720145	6.697411	5.434007	5.027428	4.790815	5.384713
22 - Manufacture of rubber and plastics products	14.55003	17.78002	18.2235	17.52535	19.19038	21.95583	25.74991	25.76039	18.06513	26.45187	30.46115	25.66352	25.48645	20.78686	19.23159	18.32647	20.59832
23 - Manufacture of other non-metallic mineral products	72.05476	88.05032	90.24652	86.78914	95.03469	108.7298	127.5189	127.5707	89.46221	130.9951	148.533	123.4632	120.9225	100.7198	93.18472	88.79904	99.8071
24 - Manufacture of basic metals	25.65068	31.34492	32.12675	30.89596	33.83128	38.70658	45.39528	45.41375	31.84754	46.63279	53.26177	44.35222	43.5515	36.10608	33.40482	31.83265	35.77881
25 - Manufacture of fabricated metal products	73.03214	89.24467	91.47066	87.96639	96.32379	110.2046	129.2486	129.3012	90.67572	132.772	151.2299	127.871	124.9751	103.2535	95.52845	91.03247	102.3174
26 - Manufacture of computer, electronic and optical products	1.470399	1.796816	1.841633	1.771079	1.939344	2.218815	2.602238	2.603297	1.825628	2.673177	3.09125	2.595602	2.580465	2.104306	1.946862	1.855234	2.08522
27 - Manufacture of electrical equipment	11.88198	14.51968	14.88184	14.31171	15.67142	17.92977	21.02813	21.03668	14.75251	21.60137	24.80038	21.05732	21.01287	17.02375	15.75001	15.00875	16.86932
28 - Manufacture of machinery and equipment n.e.c.	13.8996	16.98519	17.40885	16.74191	18.3325	20.97433	24.59881	24.60881	17.25755	25.26939	28.81219	24.44461	24.35308	19.79532	18.31424	17.45229	19.61578
29 - Manufacture of motor vehicles, trailers and semi-trailers	4.212838	5.148054	5.276459	5.074316	5.55641	6.357123	7.455668	7.458701	5.230603	7.658915	8.720742	7.330061	7.272139	5.959276	5.51342	5.253935	5.905244
30 - Manufacture of other transport equipment	1.515953	1.852482	1.898687	1.825948	1.999425	2.287555	2.682857	2.683948	1.882187	2.755993	3.147109	2.648197	2.60728	2.146104	1.98554	1.892092	2.126646
31 - Manufacture of furniture	30.91241	37.77471	38.7169	37.23364	40.77109	46.64645	54.70722	54.72947	38.38043	56.19857	63.7175	53.8036	53.11361	43.63349	40.36899	38.46905	43.2379
32 - Other manufacturing	4.072141	4.976123	5.10024	4.904848	5.370842	6.144813	7.20667	7.209601	5.055915	7.403128	8.462673	7.112299	6.979859	5.761212	5.33018	5.079319	5.708981
33 - Repair and installation of machinery and equipment	34.14498	41.72488	42.76561	41.12724	45.03461	51.52437	60.42806	60.45264	42.39394	62.07537	70.69879	59.69607	59.37126	48.44952	44.82461	42.71496	48.01016
labor in 000, head count	**517.565**	**632.46**	**648.235**	**623.401**	**682.628**	**780.999**	**915.96**	**916.333**	**642.602**	**940.93**	**1072.1**	**902.365**	**888.039**	**738.841**	**676.781**	**644.928**	**724.878**

Source: Authors' calculations based on the collected dataset.

TFP Calculation Using the Solow Residual:

We specify the Cobb-Douglas production function as:

Real GDP (Y) = A K^{α} L^{β} ……. (3)

Y represents real GDP, K denotes capital stock, L refers to labor input, and A captures TFP. Under the assumption of competitive markets and constant returns to scale, the output elasticities α and β correspond to factor income shares.

Labor income shares (β) were estimated using sectoral labor compensation data, and capital shares (α) were inferred residually. TFP is then calculated as the residual component that changes in labor and capital inputs cannot explain. The beta represents the sabor cost share in the gross value added, and - assuming constant returns to scale - the alpha is calculated as 1–beta. TFP is calculated as the residual term of the production function.

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Simple regressions show inconsistent results that overestimate α because of the common issue of reverse causality (Espinoza et al., 2013). So, we used the mathematical residual of the Cobb-Douglas formula.

Table 4. – TFP calculated for Saudi manufacturing sectors.

sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
10 - Manufacture of food products	0.749652	0.778415	0.823238	0.863643	0.841457	0.886435	0.859014	0.850767	0.870473	0.883199	0.906197	0.937022	1.116926	1.124926	1.151916	1.092457	1.181404
11 - Manufacture of beverages	3.25979	3.303251	3.534018	3.794142	3.675195	3.812408	4.034998	4.04505	4.831555	4.135614	3.739656	3.715453	2.737701	2.764038	2.769192	2.568136	2.63577
12 - Manufacture of tobacco products	1.610044	1.678677	1.771905	1.85168	1.805877	1.907332	2.119542	2.051854	1.972821	1.562483	1.404377	1.124808	1.034961	0.983378	0.932426	0.836735	0.858938
13 - Manufacture of textiles	0.67734	0.697567	0.74061	0.783035	0.761423	0.797965	0.826768	0.897709	1.051788	1.061515	1.066976	1.088703	0.726998	0.735621	0.756037	0.715745	0.764386
14 - Manufacture of wearing apparel	1.212588	1.235243	1.31825	1.408242	1.36581	1.421523	1.502725	1.560318	1.716533	1.671493	1.576588	1.661295	1.501074	1.529867	1.564218	1.47371	1.545567
15 - Manufacture of leather and related products	0.064865	0.067371	0.071242	0.07472	0.072805	0.076709	0.083895	0.084293	0.094224	0.100856	0.105609	0.107402	0.126609	0.130123	0.138693	0.135558	0.151173
16 - Manufacture of wood and of products of wood and cork	0.636788	0.654296	0.695426	0.736866	0.716134	0.749413	0.772242	0.818859	0.898775	0.875605	0.849161	0.899186	0.806158	0.825874	0.857638	0.819017	0.881931
17 - Manufacture of paper and paper products	0.533669	0.55568	0.586909	0.614104	0.598724	0.63183	0.642799	0.646395	0.671896	0.700084	0.766589	0.822254	0.811299	0.821652	0.860156	0.828472	0.911591
18 - Printing and reproduction of recorded media	1.366911	1.395225	1.487581	1.586139	1.539078	1.603876	1.771637	1.757593	1.870513	1.775147	1.717487	1.783608	1.337495	1.340319	1.362422	1.275322	1.32521
19 - Manufacture of coke and refined petroleum products	7.742366	7.075493	6.346605	6.124211	5.562037	5.188633	4.805817	4.779393	3.898194	3.861644	3.755296	3.942615	3.606838	2.321847	2.041863	1.572372	1.52016
20 - Manufacture of chemicals and chemical products	0.930163	0.966207	1.021665	1.071437	1.044004	1.100064	1.224023	1.201831	1.260432	1.046053	0.965299	0.912557	0.851018	0.805085	0.777859	0.707872	0.727432
21 - Manufacture of products and preparations pharmaceutical	4.954452	4.973172	5.344492	5.789573	5.595399	5.769672	6.016584	6.388305	7.698491	6.065457	5.379463	5.309023	5.408411	5.489365	5.454988	5.02276	5.063272
22 - Manufacture of rubber and plastics products	0.439906	0.458728	0.484169	0.505894	0.493399	0.521168	0.560014	0.602458	0.694705	0.76149	0.758494	0.808663	0.796019	0.815321	0.856988	0.829806	0.92419
23 - Manufacture of other non-metallic mineral products	1.340336	1.363559	1.456107	1.557474	1.510064	1.570339	1.330234	1.282019	1.457538	1.2446	1.156752	1.15369	1.051064	1.039013	1.027762	0.943666	0.96332
24 - Manufacture of basic metals	2.786416	2.83213	3.025648	3.239051	3.139775	3.263237	3.553185	3.881451	4.472024	4.402569	4.364788	4.750773	5.015824	5.135861	5.390081	5.163952	5.460768
25 - Manufacture of fabricated metal products	0.945809	0.972722	1.033411	1.094024	1.063481	1.113558	1.130962	1.110234	1.240623	1.245624	1.317575	1.304469	1.428306	1.488176	1.580195	1.538168	1.693757
26 - Manufacture of computer, electronic and optical products	0.357874	0.373133	0.393854	0.411583	0.401402	0.423956	0.495234	0.535044	0.576755	0.54053	0.405102	0.335168	0.332652	0.309187	0.289857	0.257412	0.261798
27 - Manufacture of electrical equipment	0.290368	0.303679	0.320078	0.333516	0.325505	0.344461	0.370631	0.360394	0.393913	0.420137	0.450254	0.438869	0.504483	0.5142	0.54617	0.532664	0.597382
28 - Manufacture of machinery and equipment n.e.c.	0.720586	0.737554	0.785345	0.835182	0.810939	0.846562	0.93134	0.907362	1.062369	1.092545	1.039611	1.022127	0.998566	1.052661	1.123172	1.09674	1.204848
29 - Manufacture of motor vehicles, trailers and semi-trailers	0.962101	0.998615	1.056318	1.108584	1.080002	1.137442	1.208735	1.301978	1.465658	1.428417	1.299462	1.14564	1.343326	1.316108	1.304806	1.204838	1.266179
30 - Manufacture of other transport equipment	1.24206	1.28439	1.361009	1.433414	1.395212	1.465952	1.570998	1.576018	1.611932	1.296016	1.095077	0.860989	0.982089	0.868751	0.811598	0.713428	0.702182
31 - Manufacture of furniture	0.630224	0.646515	0.687677	0.729761	0.708958	0.741153	0.707753	0.755095	0.840694	0.779159	0.775512	0.792497	0.941994	0.966198	0.999133	0.951175	1.018639
32 - Other manufacturing	1.090214	1.103564	1.181259	1.269496	1.229382	1.274417	1.579901	1.664074	1.841804	1.634923	1.438014	1.326666	1.625131	1.658895	1.689447	1.585232	1.642624
33 - Repair and installation of machinery and equipment	2.484983	2.48168	2.673416	2.910076	2.809052	2.887223	3.313809	3.532265	4.296745	2.929008	2.355987	2.325665	2.333288	2.361983	2.341761	2.153049	2.151613

Source: Authors' calculations based on the collected dataset.

Descriptive Findings:

On average, labor elasticity across sectors was estimated at 21.4%, implying that a 1% increase in labor input is associated with a 0.214% increase in gross value added. Capital elasticity averaged 78.6%. Figure 1 shows the estimated labor elasticity (Beta) over the study period. Other studies on Saudi Arabia's production function have yielded different results. For example, Aljebrin (2013) shows an output elasticity concerning capital and labor from 1984 to 2008 of about 0.67 and 0.57, respectively. Differences in these elasticities could result from changes in the period studied or the sectors covered. No studies in the literature cover disaggregated manufacturing sectors in Saudi Arabia; hence, this study contributes to the literature by using disaggregated data to find the determinants of TFP at the sector level.

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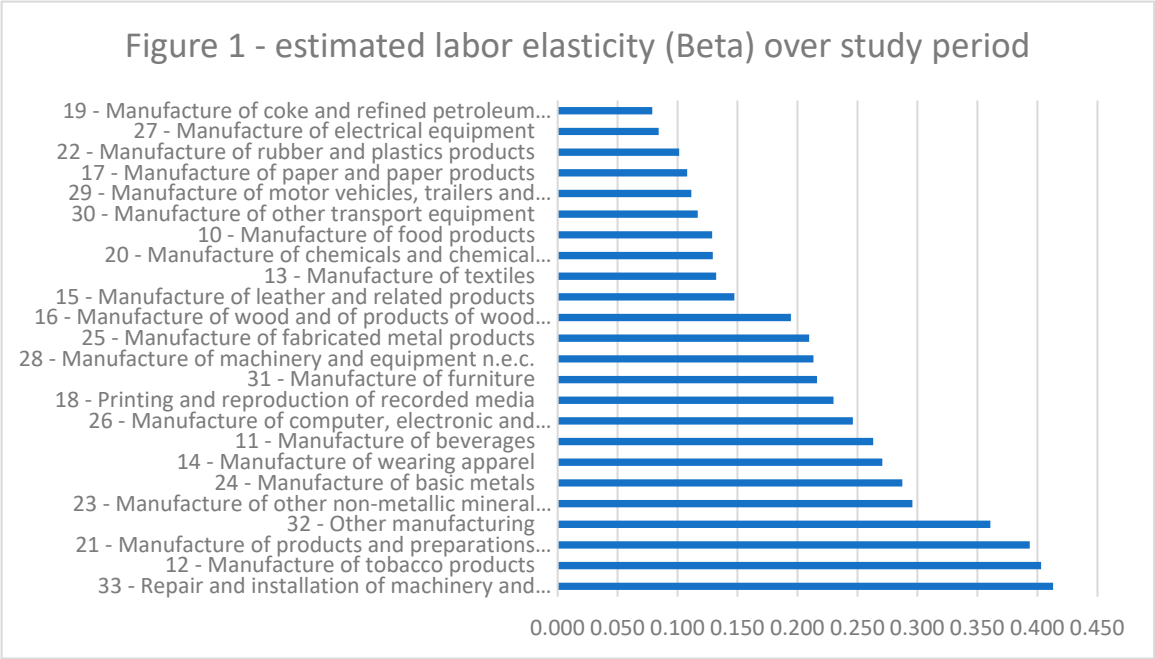

Source: Authors' calculations based on the collected dataset.

The TFP estimates reveal considerable sectoral heterogeneity. The highest average TFP was observed in manufacturing pharmaceutical products (ISIC 21), while the lowest was recorded in the leather and related products sector (ISIC 15). Regarding growth rates, the overall cumulative average annual growth rate of TFP across sectors was -0.27% during the study period, with significant variations across industries.

These TFP estimates represent the dependent variable in the subsequent empirical analysis, where we investigate the factors influencing sector-level productivity dynamics in Saudi Arabia.

In our data, the differences in elasticities among sectors reveal that the industry with the highest elasticity to labor input is the Repair and installation of machinery and equipment sector (ISIC 33) at 41.3%. In comparison, the industry with the lowest elasticity to labor input is the Manufacture of coke and refined petroleum products (ISIC 19) at 7.9%.

The manufacturing sectors in this study will likely utilize different production technologies. Therefore, the varying TFP estimations can reveal the comparative advantages among sectors in the Saudi manufacturing industry.

TFP estimates indicate that the highest average TFP was recorded in the manufacture of products and preparations in the pharmaceutical sector (ISIC 21) at 5.6. In contrast, the lowest average TFP was observed in the manufacture of leather and related products sector (ISIC 15) at 0.1. Figure 2 shows the Saudi TFP average per sector.

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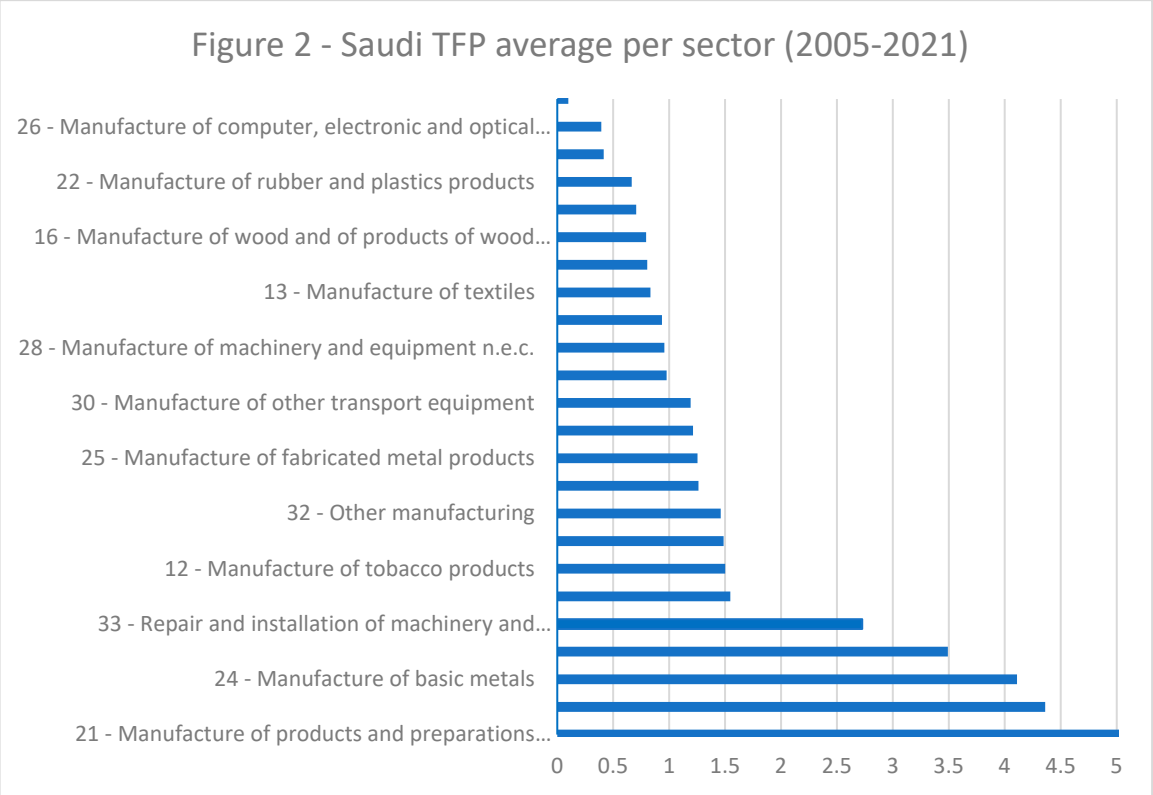

Source: Authors' calculations based on the collected dataset.

In terms of growth, the average cumulative annual growth rate for the manufacturing sector over 2005-2021 was approximately -0.27%, with varying rates across each sector. The highest TFP CAGR (about 4.7%) occurred in the Manufacture of leather and related products sector (ISIC 15), which already had the lowest TFP value. In contrast, the lowest TFP CAGR was recorded in the Manufacture of coke and refined petroleum products sector (ISIC 19) (about -9.7%). Figure 3 displays Saudi TFP growth by sector.

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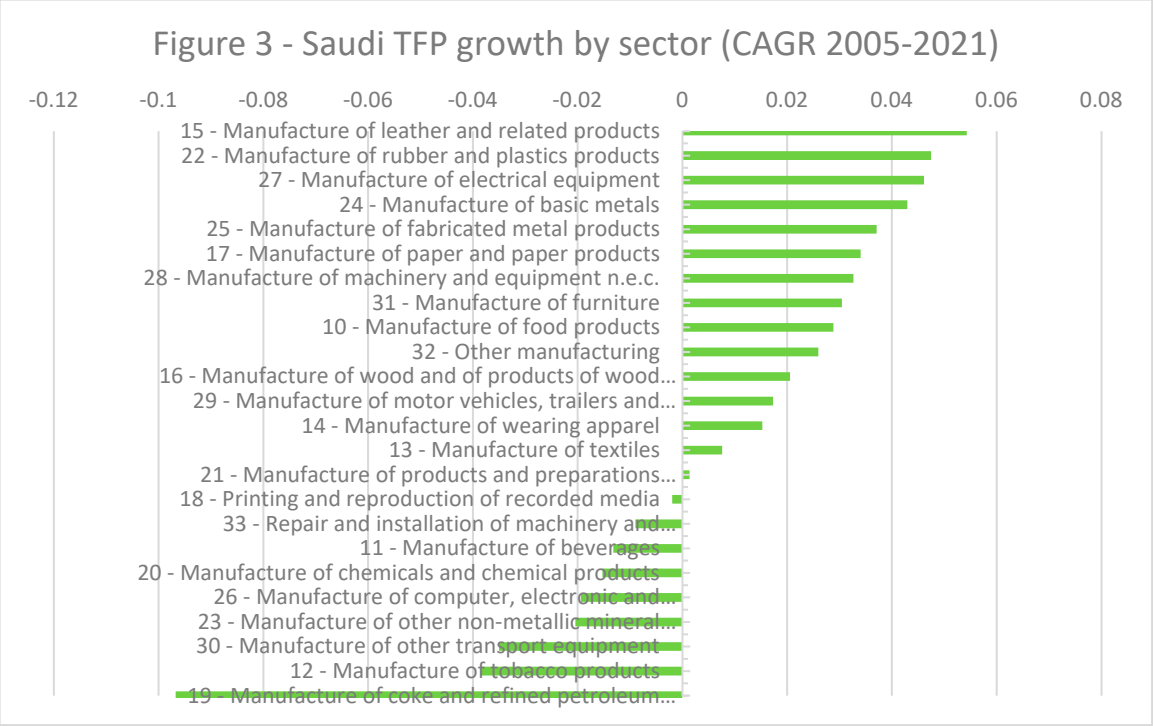

Source: Authors' calculations based on the collected dataset.

4. Methodology

4.1. Variables and Hypotheses

Building on insights from the literature, we identify six key macroeconomic variables as potential determinants of TFP across Saudi Arabia's manufacturing sectors. These variables represent both external and internal drivers of productivity and reflect the country's strategic economic transformation priorities.

Foreign Direct Investment (FDI): FDI inflows are widely associated with productivity spillovers, particularly through technology transfer and management know-how. In line with Cuevas Ahumada and Calderón Villarreal (2022), we expect FDI to influence TFP positively over the long run. We use the ratio of inward FDI to non-oil GDP to measure sectoral exposure to foreign investment. Data are sourced from the World Bank.

Human Capital (HC): Higher levels of education are presumed to facilitate innovation and the absorption of new technologies. We use the share of the labor force holding a bachelor's degree or higher as a proxy for human capital. These data are obtained from the General Authority for Statistics (GASTAT).

ICT Goods Imports (ICTM): Importing high-technology goods—particularly computers, telecommunications, and electronic components—can enhance productivity through capital deepening and digital innovation. However, excessive reliance on imported technology may impede domestic capacity building. We measure ICTM as the share of ICT goods in total goods imports, using World Bank definitions and data.

Inflation (INF): Persistent inflation is typically seen as a deterrent to productivity growth due to its distortionary effects on investment decisions and macroeconomic stability. We use annual CPI-based inflation rates from the World Bank to capture this risk.

Credit to the Manufacturing Sector (LNTC): Access to finance is essential for investing in productivity-enhancing technologies. We measure credit availability as the natural logarithm of total credit granted to the manufacturing sector, combining data from the Saudi Central Bank and the Saudi Industrial Development Fund.

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Trade Openness (TO): International trade facilitates access to new markets, technologies, and production inputs. We calculate trade openness as the ratio of non-oil exports to non-oil GDP, using GASTAT figures. This measure considers fluctuations attributable to oil exports.

4.2. Data Description

We compile an unbalanced panel dataset covering 24 ISIC-4 manufacturing sectors in Saudi Arabia over the period 2005–2021, yielding 408 observations per variable. Table 5 presents descriptive statistics for all variables, revealing substantial cross-sectoral variation.

Table 5. – Descriptive statistics of the study variables.

	TFP	FDI	HC	ICTM	INF	LNTC	TO
Mean	1.617297	0.054972	0.243519	7.353581	2.993797	11.64894	0.486459
Median	1.098402	0.033546	0.247770	7.445341	2.866269	11.88743	0.493734
Maximum	7.742366	0.171506	0.341000	8.181264	9.870248	12.12775	0.641436
Minimum	0.064865	0.002918	0.188225	6.474974	-2.093333	10.50824	0.378300
Std. Dev.	1.464900	0.051760	0.049791	0.488910	2.653178	0.517399	0.076991
Skewness	1.851427	0.903808	0.445695	-0.431783	0.505921	-1.019093	0.145061
Kurtosis	5.929783	2.497845	2.017770	2.271341	3.922102	2.758433	1.999912
Observations	408	408	408	408	408	408	408

Source: authors' calculation based on the collected dataset

Before estimation, we conduct panel unit root testing using the Im-Pesaran-Shin (IPS) method, accommodating heterogeneous dynamics across sectors. The results show that two variables (FDI and LNTC) are stationary at level, while the remaining variables are integrated of order one. None are integrated of order two. Table 6 summarizes the outcomes of the unit root test.

Table 6. – Unit Root Test Results.

Variable	Degree of integration
TFP	I-1
FDI	I-0
HC	I-1
ICTM	I-1
INF	I-1
LNTC	I-0
TO	I-1

Source: authors' calculation based on the collected dataset.

4.3. Econometric Strategy

Given the mixed integration orders and the dynamic nature of the relationships, we employ the Auto-Regressive Distributed Lag (ARDL) panel modeling approach. Specifically, we use the Pooled Mean Group (PMG) estimator, which assumes homogenous long-run coefficients but allows for heterogeneity in short-run dynamics and error variances across sectors.

The model specification is given as:

$$\Delta TFP_{it} = \theta_i (TFP_{i\,t-1} - \lambda'_i X_{it}) + \alpha_{i1} \Delta TFP_{it-1} + \beta'_{i1} (\Delta TO_{it-1} + \Delta HC_{it-1} + \Delta ICTM_{it-1} + \Delta FDI_{it-1} + \Delta LNTC_{it-1} + \Delta INF_{it-1}) + \Phi_i + \varepsilon_{it.} \quad \ldots\ldots\ldots (4)$$

Where:

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- TFP_{it} is the total factor productivity of sector i at time t
- $\lambda'_i X_{it}$ is the vector of independent variables
- $\lambda'i$ denotes long-run coefficients
- θi is the speed of adjustment
- Φ_i captures sector-specific fixed effects
- ε_{it} is the error term
- $(TFP_{i\,t-1} - \lambda'_i X_{it})$ is the error correction term (ECT)
- α and β represent short-term dynamic coefficients

Lag length was determined using the Akaike Information Criterion (AIC), which indicated an optimal structure of (1,1,1,1,1,1,1). The Hausman test supports using the PMG estimator, as the null hypothesis of slope homogeneity cannot be rejected ($p > 0.05$).

5. Results and Discussion

5.1. Long-Run Results

Table 7 presents the long-run estimates from the panel ARDL model using the Pooled Mean Group (PMG) estimator. All six explanatory variables are statistically significant at the 5% level. The coefficients' signs and magnitudes are broadly consistent with theoretical expectations, providing clear implications for productivity policy in Saudi Arabia.

Table 7. Results of the ARDL long-run equation.

Variable	Coefficient	Std. Error	t-Statistic	P value
FDI	0.373	0.155	2.410	0.0168***
HC	4.419	0.267	16.518	0.000***
ICTM	-0.275	0.015	18.921	0.000***
INF	-0.035	0.003	11.653	0.000***
LNTC	0.161	0.009	17.737	0.000***
TO	3.209	0.160	20.074	0.000***

*** significant at 5% level. Source: authors' calculation based on the collected dataset.

Specifically, foreign direct investment (FDI) positively contributes to TFP in the long run, with a 1% increase in the FDI-to-non-oil-GDP ratio associated with a 0.37% increase in TFP. This underscores the potential for FDI to drive knowledge spillovers and modernize industrial capabilities.

Human capital exerts a powerful effect. The coefficient estimate indicates that a one percentage point increase in the share of highly educated labor leads to a 4.42% increase in TFP. This suggests that long-term productivity growth in Saudi Arabia hinges critically on investment in advanced skills and education.

Credit to the manufacturing sector also yields a significant and positive effect, affirming the importance of financial access for productivity-enhancing investments. Trade openness has the second-largest impact among all variables, with a 1% increase associated with a 3.21% gain in TFP, highlighting the decisive role of global integration in raising sectoral efficiency.

Conversely, inflation and ICT goods imports negatively impact TFP in the long run. The negative coefficient on ICT imports (–0.275) suggests inefficiencies in the absorption or application of imported technologies. Similarly, the adverse effect of inflation (–0.035) highlights the risks

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associated with macroeconomic instability, even in an environment of generally moderate price levels.

5.2. Short-Run Dynamics and Error Correction

The short-run results, shown in Table 8, reveal a more selective pattern of significance. Only two variables—FDI and trade openness—are statistically significant in the short term. Interestingly, the FDI coefficient is negative in the short run, suggesting initial adjustment costs or time-lagged absorption of foreign investment benefits. In contrast, trade openness exerts a positive and immediate effect, indicating that external market access can deliver quicker productivity gains.

Table 8. Results of Short-Run Equation.

Variable	Coefficient	Std. Error	t-Statistic	P value
COINTEQ01	-0.309	0.073	-4.251	0.0000***
D(FDI)	-2.492	0.614	-4.057	0.0001***
D(HC)	-0.868	0.803	-1.081	0.2808
D(ICTM)	0.013	0.018	0.738	0.4611
D(INF)	0.002	0.006	0.465	0.6427
D(LNTC)	0.001	0.179	0.054	0.9570
D(TO)	0.481	0.227	2.114	0.0357***
Constant	-0.137	0.130	-1.050	0.2948

Source: authors' calculation based on the collected dataset.

The error correction term (ECT) is negative and significant (–0.309), confirming the presence of a stable long-run relationship among the variables. Its magnitude implies that approximately 31% of deviations from the long-run equilibrium are corrected yearly, suggesting moderate adjustment dynamics across sectors.

5.3. Sectoral Heterogeneity and Policy Implications

An analysis of sector-specific short-run coefficients reveals considerable heterogeneity. For instance, sectors such as leather products (ISIC 15), textiles (ISIC 13), and rubber and plastics (ISIC 22) exhibit adverse short-run effects from FDI and human capital, implying transitional frictions or mismatches in absorptive capacity.

ICT imports exert positive short-term effects in most sectors (14 of 24), indicating that imported technology provides some immediate productivity benefits. However, the persistent negative long-term effect suggests an underutilization or misalignment of technology with local capabilities over time. Policymakers may need to enhance domestic R&D or technical skills to harness these imports better.

Inflation exhibits mixed short-term impacts. While it depresses productivity in sectors such as basic metals (ISIC 24) and pharmaceuticals (ISIC 21), it is positively associated with TFP in others. This variation may reflect sector-specific input cost structures and pricing power.

Financial credit shows short-run significance in only a few sectors, with inconsistent direction. Some industries experience productivity gains from credit expansion (e.g., printing, ICT products), while others show negative associations, likely due to inefficiencies in credit allocation or delayed investment returns.

Trade openness has broad short-run significance across most sectors, reinforcing its role as a near-universal productivity driver in the Saudi manufacturing context.

These heterogeneous patterns emphasize the importance of tailored industrial policies. For example, sectors lagging in FDI absorption or R&D capacity may benefit from targeted vocational

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training, regulatory reform, or innovation support programs. The findings also support Saudi Arabia's Vision 2030 goals of diversifying exports, enhancing financial services, and investing in human capital.

Table 9. – Short-term significant variables by sector.

ID	Sector (ISIC 4 – 2 digits)	Highly significant D variables (at 5%) with sign
1	10 - Manufacture of food products	ICTM (+), INF (+), LNTC (-), TO (+)
2	11 - Manufacture of beverages	ICTM (-), INF (+),
3	12 - Manufacture of tobacco products	ICTM (+), INF (+), TO (+)
4	13 - Manufacture of textiles	FDI (-), ICTM (-), INF (+), TO (-)
5	14 - Manufacture of wearing apparel	FDI (-), HC(-), ICTM (+), INF (+), LNTC (-), TO (-)
6	15 - Manufacture of leather and related products	FDI (-), HC(-), ICTM (+), INF (+), LNTC (-), TO (+)
7	16 - Manufacture of wood and of products of wood and cork	FDI (-), ICTM (+), INF (+), LNTC (-), TO (+)
8	17 - Manufacture of paper and paper products	FDI (-), HC(-), ICTM (+), INF (+), LNTC (-), TO (+)
9	18 - Printing and reproduction of recorded media	ICTM (+), INF (+), LNTC (+)
10	19 - Manufacture of coke and refined petroleum products	ICTM (-), INF (-), LNTC (+), TO (-)
11	20 - Manufacture of chemicals and chemical products	ICTM (+), INF (+), TO (+)
12	21 - Manufacture of products and preparations pharmaceutical	INF (-)
13	22 - Manufacture of rubber and plastics products	FDI (-), HC (-), ICTM (+), INF (+), LNTC (-), TO (+)
14	23 - Manufacture of other non-metallic mineral products	ICTM (-), INF (+)
15	24 - Manufacture of basic metals	ICTM (-), INF (-)

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16	25 - Manufacture of fabricated metal products	ICTM (+), INF (+), LNTC (-), TO (+)
17	26 - Manufacture of computer, electronic and optical products	ICTM (-), INF (-), LNTC (+), TO (+)
18	27 - Manufacture of electrical equipment	FDI (-), HC(-), ICTM (+), INF (+), LNTC (-), TO (+)
19	28 - Manufacture of machinery and equipment n.e.c.	FDI (-), ICTM (+), INF (+), LNTC (-), TO (+)
20	29 - Manufacture of motor vehicles, trailers and semi-trailers	FDI (-), ICTM (+), INF (+), LNTC (-), TO (+)
21	30 - Manufacture of other transport equipment	ICTM (+), INF (+), TO (+)
22	31 - Manufacture of furniture	ICTM (+), INF (+), LNTC (-), TO (+)
23	32 - Other manufacturing	FDI (-), ICTM (+), INF (+), LNTC (-), TO (+)
24	33 - Repair and installation of machinery and equipment	INF (-)

Source: authors' calculation based on the collected dataset.

6. Conclusion and Policy Recommendations

This study investigates the key macroeconomic determinants of Total Factor Productivity (TFP) across 24 manufacturing sectors in Saudi Arabia from 2005 to 2021, utilizing a panel ARDL framework with a Pooled Mean Group (PMG) estimator. The findings confirm that FDI, human capital development, credit expansion, and trade openness significantly contribute to long-run productivity gains. At the same time, inflation and over-reliance on ICT imports negatively impact productivity. Only FDI and trade openness display consistent significance in the short run, with FDI initially exhibiting a negative sign before becoming positive in the long run.

The results emphasize the importance of long-term strategic investment in human capital and infrastructure that enhances absorptive capacity, particularly in sectors lagging in productivity. Trade openness has immediate and lasting effects, reinforcing the value of policies that reduce non-tariff barriers, streamline export procedures, and diversify markets beyond oil.

The persistent adverse effect of ICT imports, despite their short-term benefits, signals a structural challenge: technology is entering the country but is not being effectively translated into sustained productivity. This calls for more substantial alignment between technology policy and domestic innovation capacity. Similarly, inflation's adverse impact on long-term productivity stresses the need for a credible macroeconomic policy framework to preserve investor confidence and maintain operational stability in manufacturing.

These insights are directly relevant to Saudi Arabia's Vision 2030 goals. Policymakers aiming to revitalize the industrial sector should prioritize educational reform, targeted sector-specific credit schemes, and policies that encourage knowledge spillovers from international investment. Tailored

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strategies will be essential, as the observed sector-level heterogeneity in this study suggests that a one-size-fits-all approach will likely be ineffective.

While this study offers novel evidence using disaggregated data, it has limitations. The use of Cobb-Douglas production assumptions may not fully capture sectoral technological differences. Additionally, due to data constraints, unobserved firm-level characteristics—such as management practices and labor quality—are not accounted for. Future research could extend this framework using firm-level data or consider dynamic interactions between technology imports, R&D investment, and institutional quality.

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