THE ECONOMIC CONTRIBUTION OF HALEON TO THE USA IN 2021

A REPORT FOR HALEON

OCTOBER 2022

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EXECUTIVE SUMMARY

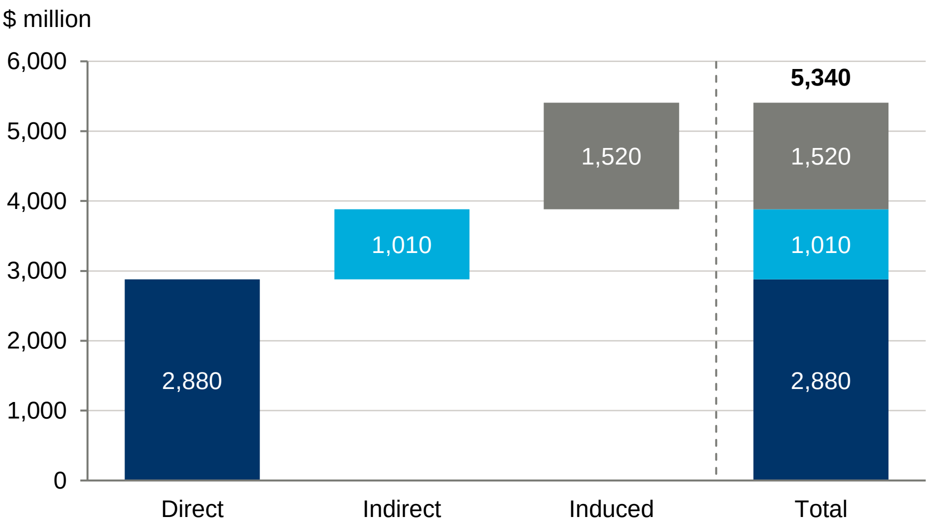
Haleon commissioned Oxford Economics to quantify its economic contribution to the USA economy in 2021. This report describes the size of Haleon's economic contribution in terms of gross value added (GVA), jobs, and wages. It also considers the wider economic benefits of its activity, through investment in research & development (R&D), exports, and charitable donations.

Oxford Economics calculates that Haleon's total contribution to USA GDP was $5.34 billion in 2021. Haleon directly generated $2.88 billion of GVA, and spent $1.22 billion on the procurement of goods and services, of which $1.17 billion was spent domestically, generating a further $1.01 billion of GVA along the domestic supply chain. In addition, $1.52 billion was generated through induced effects as a result of Haleon employees and those along the domestic supply chain spending their incomes within the economy.

$5.34 billion
contribution to GDP in 2021.

Haleon makes a substantial contribution to the USA economy.

Fig. 1. Total GVA contribution to GDP, USA, 2021



Source: Haleon, Oxford Economics. Note: may not sum due to rounding.

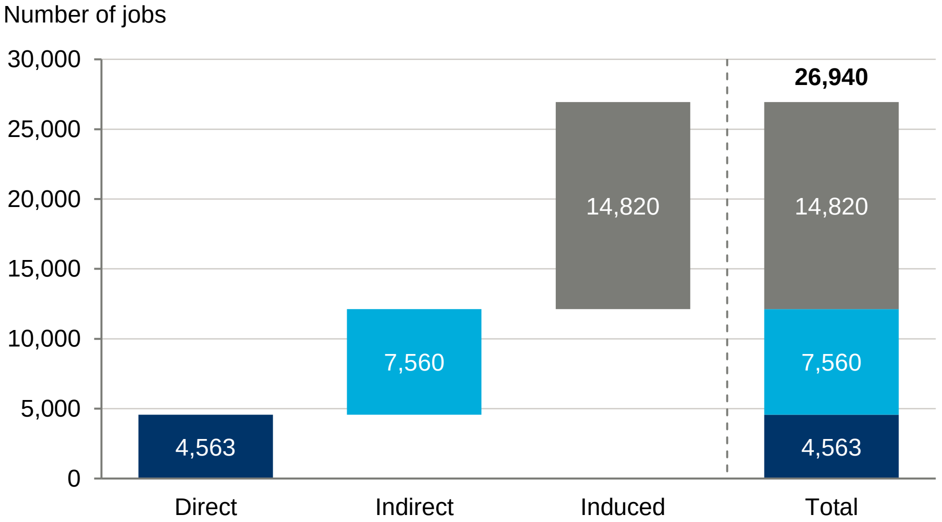
Haleon supported an estimated 26,940 jobs across the USA in 2021. It directly employed 4,563 workers. Through stimulating additional supply chain (indirect) activity, Haleon supported 7,560 jobs. Approximately 14,820 further jobs were supported through wage consumption (induced) effects. In total, this equates to almost five jobs across the wider economy for every job directly employed by Haleon.

26,940 jobs

sustained in 2021.

Almost five jobs across the wider economy for every job employed directly by Haleon.

Fig. 2. Total contribution to employment, USA, 2021



Source: Haleon, Oxford Economics. Note: may not sum due to rounding.

Haleon makes a positive contribution to boosting USA productivity, which is defined as the average GVA produced by each member of the workforce. Productivity is a key determinant of pay and living standards in the long-run. Haleon's direct operations support an average productivity of $630,600 per job, more than four-and-a-half times higher than the national average ($136,400 per job).

Haleon's highly productive workforce is relatively well remunerated. In total, its direct workforce earned $1.39 billion in wages—equivalent to $297,300 per job. Average direct earnings are therefore almost six-times higher than the USA average ($50,900 per job). In total, Haleon supported $2.87 billion in wages across the USA.

Haleon makes a substantial investment in research and development (R&D). In 2021, it spent $338 million on R&D investment globally, of which $154 million was spent in the USA, equivalent to 3.7% of direct economic output (turnover). R&D currently accounts for 3.5% of USA GDP, therefore Haleon has above average R&D research intensity. A large part of this investment was to support Haleon's strategy of investing in power brands and local stars research and product development activities.

Haleon's R&D spending can drive economic growth across the USA economy. Our analysis indicates that this research-led innovation enhances the growth potential of the overall economy. We find that Haleon's R&D spending in 2021 alone generated a GDP boost of $57 million by 2031. Of this, 78% of the benefits are realised due to research in the manufacturing of pharmaceutical products sector, the sector within which consumer healthcare products are categorised. The remaining 22% is realised in the rest of the economy as the benefits of innovation are spread widely.

Haleon also makes a positive contribution to USA exports. In 2021, it sold $60 million of goods abroad. The main export markets for Haleon's products include Central America, Canada, and Mexico, with these markets collectively accounting for more than two-thirds ($42 million) of export sales from the USA.

Fig. 3. A summary of Haleon's economic contribution, USA, 2021

$5.34 billion GVA contribution to GDP
$2.88 billion direct contribution

26,940 jobs supported across the USA
For every direct job, almost further five jobs are supported

$2.87 billion supported in total wages
$1.36 billion to the direct workforce, or $263,100 per job

$154 million investment in R&D
Generating a $57 million boost to USA GDP by 2031

$60 million of manufacturing exports
Equivalent to 1.5% of turnover

Source: Haleon, Oxford Economics

1. INTRODUCTION

1.1 BACKGROUND

In July 2022, GSK Consumer Healthcare separated from GSK and formed Haleon, a standalone company 100% focused on consumer health and listed on the London Stock Exchange.[1]

Haleon specialises in the research, development and manufacture of consumer health products in a number of areas, including oral health, pain relief, cold and flu, allergy, digestive health, and vitamin and mineral supplements.[1] In 2021, Haleon delivered sales of £9.5 billion ($13 billion) globally across a portfolio of household-recognised brands, such as **Sensodyne**, **Polident**, **Voltaren**, and **Panadol**.[1]

Haleon is notable for its focus on innovation, having delivered more than 250 innovative products over the past five years.[1]

The company supports more than 4,500 employees across the USA and its territories. This includes employees at its manufacturing sites in Oak Hill, New York; Lincoln, Nebraska; St Louis, Missouri; and Guayama, Puerto Rico. These sites produce a range of products including **Excedrin**, **Tums**, **Sensodyne**, **Polident**, and **paradontax**. Haleon has its US headquarters in Warren, New Jersey and also has an R&D centre in Richmond, Virginia.

It is estimated that 88.8 million American households, or 70%, have purchased at least one Haleon product in 2021.[2]

Haleon commissioned Oxford Economics to quantify its economic contribution to the American economy. Our analysis reflects the diverse range of activities that Haleon is engaged in, ranging between the manufacture and sale of products, research and development of new products, and business operations, such as human resources, IT, and finance.

1.2 REPORTING STRUCTURE

This report is structured as follows:

- **Section 2** presents Haleon's contribution to the USA economy. In doing so we discuss turnover, GVA contributions to GDP, sectoral impacts and supply chain spending;
- **Section 3** presents Haleon's employment and wage contribution;
- **Section 4** discusses the wider benefits of Haleon's R&D investment, exports, and charitable donations; and
- **Appendix 1** details our method.

[1] www.haleon.com

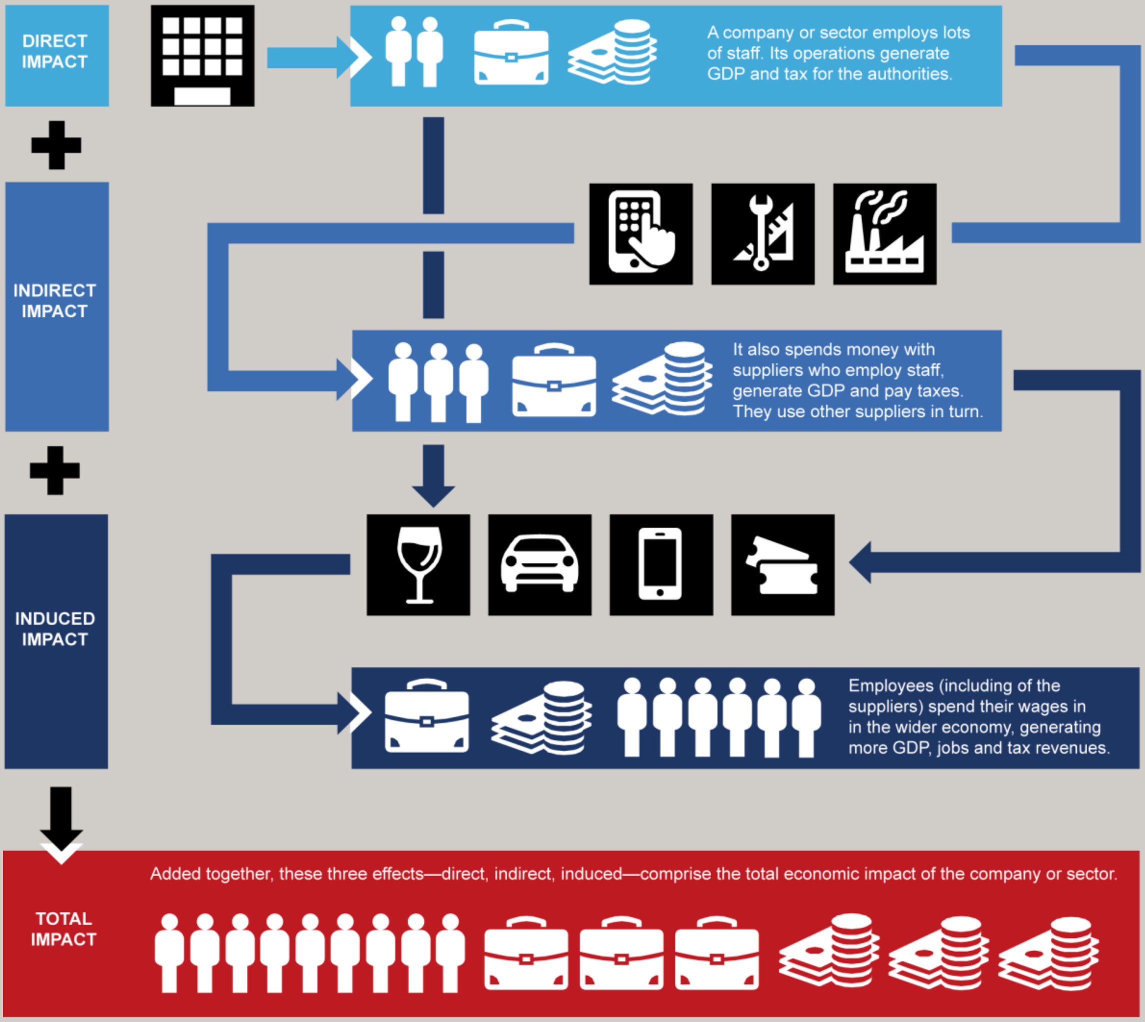
[2] Source: Haleon.

BOX 1: AN INTRODUCTION TO ECONOMIC IMPACT ANALYSIS

The economic impact of a firm or industry is measured using a standard means of analysis called an economic impact assessment. The report quantifies the three 'core' channels of impact that comprise the organisation's 'economic footprint':

- **Direct impact**: the economic benefit of Haleon's operations and activities in the USA, including its direct gross value added (GVA) contribution to GDP, employment, and wages;
- **Indirect impact**: captures the economic benefit and employment stimulated by Haleon's procurement of goods and services from its domestic supply chain, both through purchases made by Haleon from its suppliers, and subsequent spending through further rounds of purchases; and
- **Induced impact**: comprises the wider economic benefits that arise from the payment of wages by Haleon, and the firms in its domestic supply chain, to staff who spend a proportion of this income through their household's consumption.

Fig. 4. Economic impact assessment



Source: Oxford Economics

From these channels, Haleon's total economic footprint in the USA economy is presented, using three key metrics:

- GDP, or more specifically, Haleon's gross value added (GVA) contribution to USA GDP;[3]
- Employment, as the number of people employed (jobs); and
- Wages, paid to the workforce.

In addition to the core economic impacts, this report examines the wider effects of its operations in boosting economic activity elsewhere in the economy. These impacts represent the wider benefits that governments, consumers, society, and other industries derive from the goods and services Haleon provides. For Haleon, these are captured in the contribution made to research & development (R&D), exports, and charitable donations.

The modelling on which this report is based computes the economic footprint of Haleon in the USA in 2021. The results are presented on a gross basis, and therefore ignore any displacement of activity from Haleon's competitors or other firms. Nor do they consider what the resources used by Haleon, or stimulated by its expenditure, could alternatively produce their second-most productive usage.

Further detail about the economic impact methodology is included in Appendix 1.

[3] Gross domestic product (GDP) is the main indicator of economic activity in the USA, used to measure the rate of growth or decline in the economy, and when it enters a recession.

2. HALEON'S CONTRIBUTION TO GDP

KEY FINDINGS

- Haleon's American operations generated $4.10 billion of turnover (economic output) in 2021, including a **$2.88 billion direct GVA contribution to USA GDP**.
- Haleon spent $1.22 billion on the purchases of goods and services for its American operations — $1.17 billion of which was spent domestically. Domestic spending supported additional GVA, through Haleon's direct suppliers, and along the wider supply chain. We estimate that this **indirect effect generated $1.01 billion of GVA**.
- The households of Haleon's employees, and those supported by its supply chain spending, spend a proportion of their wages at retail, leisure, and other outlets. This stimulates economic activity at these firms, and also along their supply chains. We estimate that this **induced effect generated $1.52 billion of GVA**.
- In total, Haleon therefore made a **$5.34 billion GVA contribution to GDP in 2021**. All sectors of the economy benefit from Haleon's activity.
- **Haleon's operations are highly productive**, averaging $630,600 per job. This is four-and-a-half times higher than average productivity across the USA economy.

2.1 INTRODUCTION

This chapter investigates the contribution that Haleon made to USA GDP in 2021. It considers its direct activity, the economic activity it stimulates through procurement, and the household consumption of wages paid to workers.

2.2 A SUBSTANTIAL CONTRIBUTION TO THE USA ECONOMY

To calculate its contribution to the USA economy, we draw on financial data provided by Haleon.

In 2021, Haleon's operations in the USA generated an overall turnover of $4.10 billion. Almost 30% of total turnover was spent on the procurement of goods and services from its suppliers, which amounted to $1.22 billion, of which $1.17 billion were purchased from domestically based suppliers. **The remaining $2.88 billion therefore represents Haleon's direct GVA contribution to USA GDP.** This constitutes the compensation of employees (wages plus social security and pension contributions) and gross operating surplus generated through its operations.[4]

Haleon's positive contribution to the USA economy extends past the contribution it makes directly through its own operations. This is because Haleon makes purchases of inputs of goods and services from other firms in order to produce its output. This spending stimulates additional activity along its domestic supply chain. This is referred to as the *indirect* impact. In 2021, we

[4] Note that this represents an underestimate of Haleon's direct GVA in 2021, as it excludes both direct taxes on production (e.g. business rates and the apprenticeship levy) and employer National Insurance Contributions (NICs) as well as corporation tax and VAT payments made by Haleon in the relevant period.

estimate that Haleon's procurement stimulated a $1.01 billion GVA contribution to USA GDP along its supply chain.

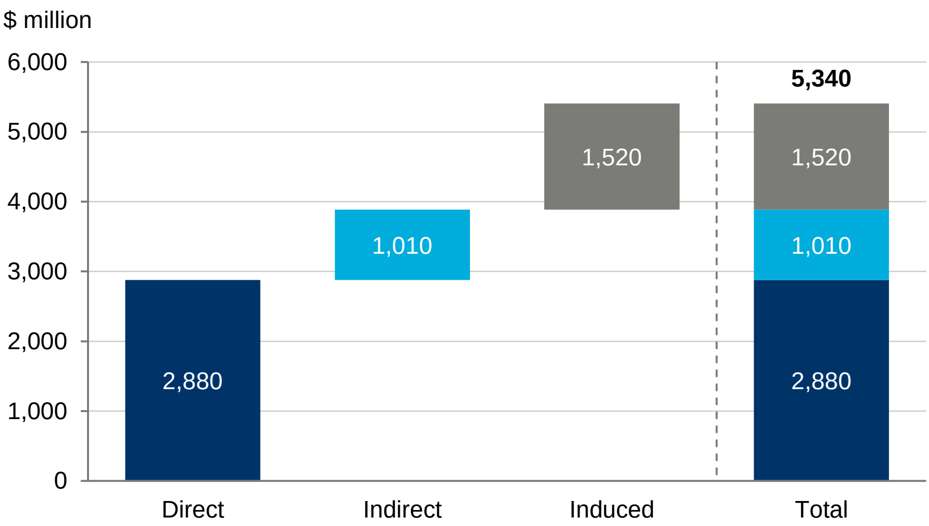
The households of Haleon's employees, and those supported by its supply chain spending, spend a proportion of their wages at retail, leisure, and other outlets. This stimulates economic activity at these firms, and also along their supply chains. This is referred to as the *induced* impact. In 2021, we estimate the household wage consumption of Haleon's employees and those of its suppliers stimulated a further $1.52 billion GVA contribution to USA GDP.

In total, Haleon supported $5.34 billion of GVA contributions to GDP in 2021.[5] Consequently, Haleon's American operations had a GVA multiplier of 1.85, meaning that for every $100 directly generated, a further approximately $35 of supply chain (indirect) and $53 of wage consumption (induced) GVA was generated across the USA.

Fig. 5. Total GVA contribution to GDP, USA, 2021

$5.34 billion

Haleon's total gross value added contribution to USA GDP in 2021.



Source: Haleon, Oxford Economics. Note: may not sum due to rounding.

2.3 LABOUR PRODUCTIVITY

Calculating the direct contribution of Haleon to USA GDP allows the measurement of labour productivity — that is, average value added to the USA economy on a per job basis. Having high productivity workers is important as it can enhance the price competitiveness of Haleon's goods and services, and boost their profit margin, both of which potentially add to GDP. In turn, this raises the standard of living of USA residents.

Haleon's operations are highly productive. We estimate that Haleon's operations averaged $630,600 of GVA per job in 2021. This is four-and-a-half times the national average ($136,400 per job), and is more productive than all other sectors of the economy, including capital-intensive industries such as

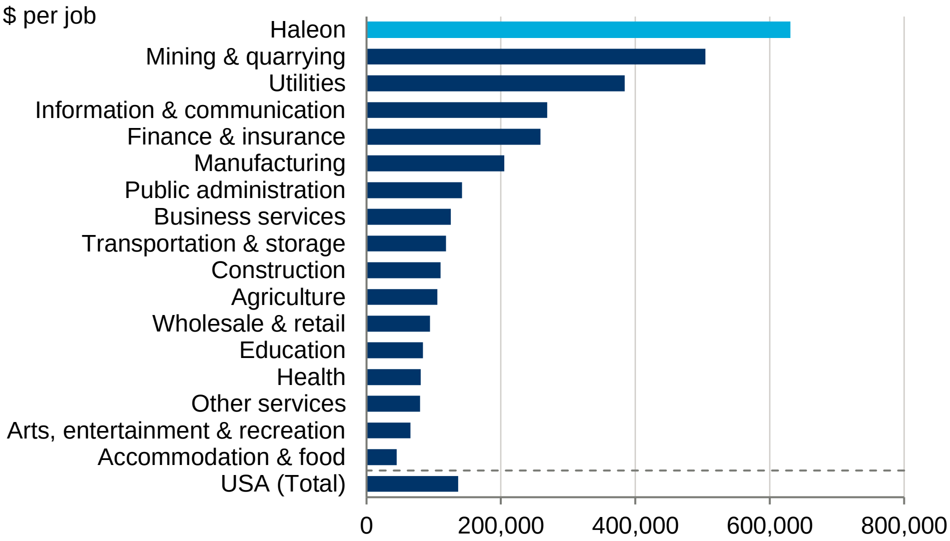
[5] The combined GVA from direct and indirect (supply chain) activity ($3.89 billion) is less than total revenue ($4.10 billion), as both Haleon and firms along its supply chain draw on imports, the GVA associated with which is realised abroad.

mining & quarrying and utilities, and services such as information & communication and finance & insurance.[6] Indeed, Haleon's direct operations are more than two-and-a-half times more productive than the manufacturing sector as a whole ($204,800 per job).

$630,600

Haleon's operations are four-and-a-half times more productive than the national average.

Fig. 6. A comparison of Haleon and sectoral productivity, USA, 2021



Source: Haleon, Oxford Economics. Note: may not sum due to rounding.

2.4 ECONOMIC BENEFITS ARE FELT ACROSS THE ECONOMY

As well as quantifying the impact of Haleon on the USA economy as a whole, we have also estimated its impact at a sectoral level. Through the direct, indirect, and induced channels of impact, Haleon's activity benefits all sectors of the American economy.

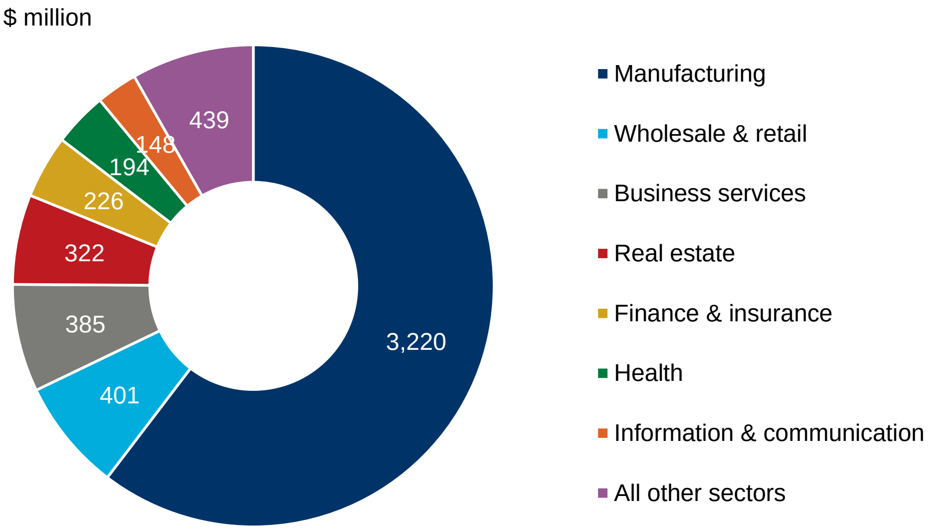
We find that approximately three-fifths of all GVA contributions to USA GDP are in the manufacturing sector, equating to $3.22 billion. This largely arises from Haleon's direct operations across the USA, which generated $2.88 billion of manufacturing GVA. This sector benefits from a further $310 million of GVA generated along the domestic supply chain, and $103 million through induced effects.

Wholesale & retail benefits from the second-largest GVA impact ($401 million), due to both supply chain ($199 million) and wage consumption ($202 million) effects. Business services ($385 million) is the third most-affected sector, primarily due to supply chain effects ($215 million).

[6] Note that this analysis excludes real estate activities, where GVA and therefore productivity estimates are distorted by imputed rents, and are therefore do not reflect the productivity of workers operating in this sector.

Through the direct, indirect, and induced channels of impact, Haleon's activity benefits all sectors of the USA's economy.

Fig. 7. Total GVA contribution to GDP by sector, USA, 2021



Source: Haleon, Oxford Economics. Note: may not sum due to rounding.

3. HALEON'S CONTRIBUTION TO EMPLOYMENT

KEY FINDINGS

- Haleon **directly employed 4,563 workers across its USA operations** in 2021. Approximately half of the workforce was employed at its three largest USA sites: Guayama (Puerto Rico), Warren (New Jersey), and Lincoln (Nebraska).
- The domestic supply chain activity stimulated by its procurement spending, and further spending along the domestic supply chain, created an estimated **7,560 indirect jobs** in the USA in 2021.
- The households of Haleon's employees, and those supported by its supply chain spending, supported a further **14,820 induced jobs** in the USA in 2021.
- In total, Haleon supported **a total of 26,940 jobs across the USA workforce** in 2021, across all sectors of the economy. Each direct job therefore supported almost five further jobs across the wider USA economy on average.
- Haleon's **workforce is relatively well-remunerated**: average wages equated to $297,300 per direct job, almost six-times higher than the national average. Across its entire economic footprint, it supported $2.87 billion in wages.

3.1 INTRODUCTION

This chapter focuses on the employment impacts of Haleon's activity in the USA. We consider the workforce employed directly, the jobs supported along the domestic supply chain, and how wage consumption supported further employment across the USA economy.

3.2 CONTRIBUTION TO EMPLOYMENT

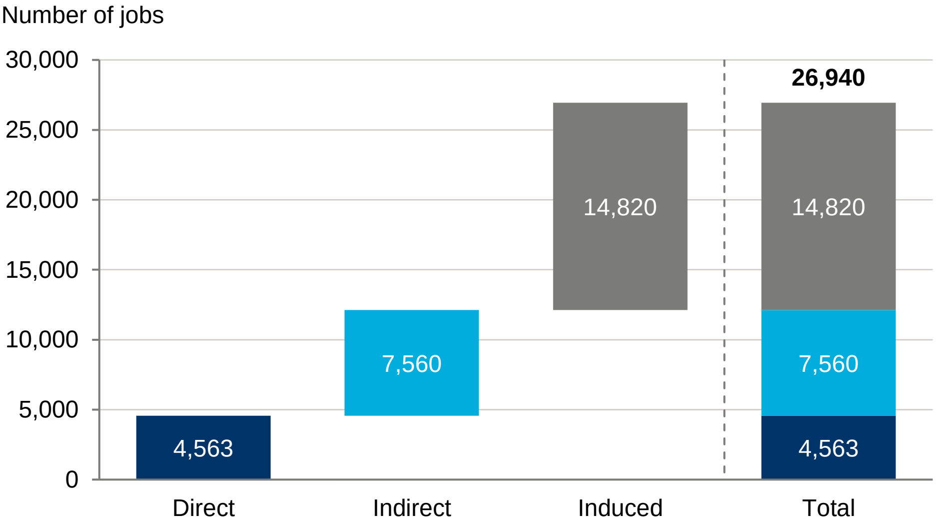
In 2021, Haleon employed approximately 4,563 workers in the USA. A majority of the workforce (3,360 workers) were employed on a permanent basis, alongside 1,203 contingency workers. Guayama, Puerto Rico supported the most jobs of any site (1,213 jobs), alongside Warren, New Jersey (751 jobs), and Lincoln, Nebraska (596 jobs).

In total, **we estimate that Haleon supported 26,940 jobs across the USA economy in 2021**. Approximately 7,560 jobs are supported along Haleon's domestic supply chain, with a further 14,820 jobs as a result of wage consumption. This equates to almost five further jobs across the wider American economy for every job directly employed by Haleon.

26,940 jobs

Employment supported across the USA in 2021.

Fig. 8. Total employment, USA, 2021



Source: Haleon, Oxford Economics. Note: may not sum due to rounding.

3.3 COMPOSITION OF EMPLOYMENT

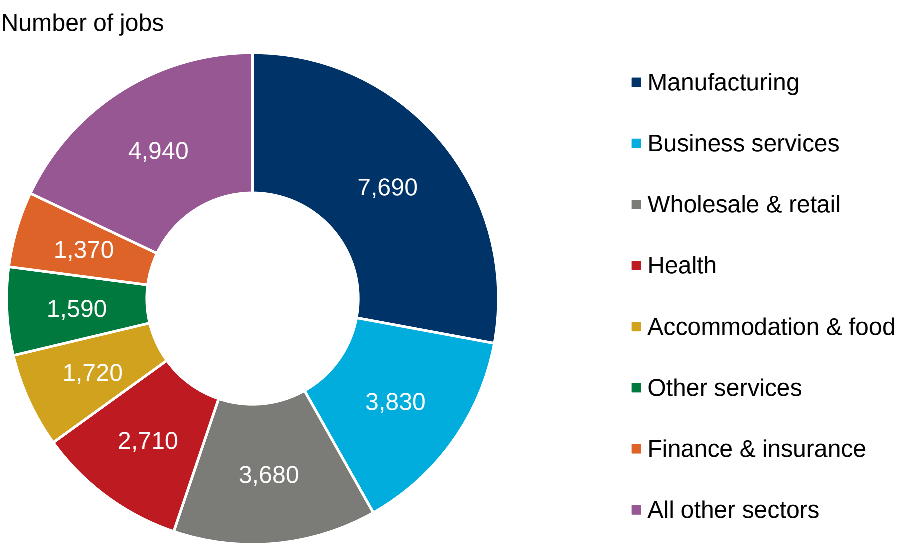
Through stimulating supply chain and wage consumption spending, **Haleon supported employment across all sectors of the economy.**

Employment impacts (like GVA) were largest in the manufacturing sector, which accounted for 7,960 jobs, or just over a quarter of total employment. This is somewhat lower than the equivalent share of GVA across Haleon's economic footprint, a reflection of both the highly-productive nature of both Haleon's direct operations, and manufacturing firms more generally.

Business services (3,830 jobs), wholesale & retail (3,680 jobs), and health (2,710 jobs) all similarly benefitted from Haleon's activity in the USA.

> Through stimulating supply chain and wage consumption spending, Haleon supported employment across all sectors of the economy.

Fig. 9. Employment by sector, USA, 2021



Source: Haleon, Oxford Economics. Note: may not sum due to rounding.

3.4 WAGES

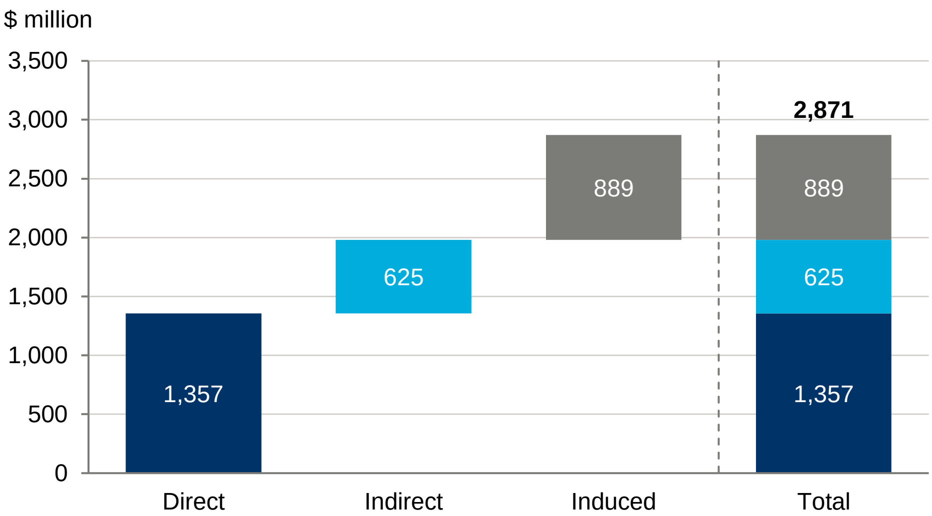
Haleon's highly productive workforce is relatively well-remunerated. In total, its workforce earned $1.36 billion in wages—equivalent to $297,300 per job. Average direct earnings are almost six-times higher than the national average ($50,900 per job).

Employment supported across the domestic supply chain earned a further $625 million, while wage consumption generated a further $889 million in wages. Across its entire economic footprint, Haleon therefore supported $2.87 billion in wages.

$2.87 billion

Total wages earned across Haleon's total economic footprint.

Fig. 10. Total wages, USA, 2021



Source: Haleon, Oxford Economics. Note: may not sum due to rounding.

4. HALEON'S WIDER ECONOMIC CONTRIBUTION

KEY FINDINGS

- **Haleon makes a substantial investment into research & development (R&D)**. In 2021, it invested $338 million in R&D globally, of which $154 million was spent in the USA. This equates to 3.7% of turnover across the USA, forming a positive contribution to overall R&D investment across the national economy, where R&D investment represents 3.5% of GDP.
- Building on the quantitative relationship between R&D spending and GDP gains, we estimate that this R&D investment in 2021 alone will generate **a $57 million boost to USA GDP by 2031**.
- Haleon also makes a **positive contribution to USA exports**. In 2021, it made $60 million of sales abroad, equivalent to 1.5% of turnover. Key export markets for Haleon's products manufactured in the USA include Central America, Canada, and Mexico.
- Haleon also contributes to American society through **charitable donations**. In 2021, Haleon made $674,000 in charitable donations across the USA across a range of charities and not-for-profit organisations.

4.1 RESEARCH & DEVELOPMENT INVESTMENT AND SPILLOVER EFFECTS

Haleon makes a substantial investment in research and development (R&D). In 2021, it spent $338 million on R&D investment globally, of which $154 million (46%) was spent in the USA, equivalent to around 3.7% of turnover. Haleon therefore makes a higher investment in R&D than the USA economy as a whole, where R&D spending equated to 3.5% of GDP in 2020.[7] Clinical trials form part of Haleon's R&D activity, with 10 clinical trials across the USA in 2021, with 708 participants. The trials were largely focussed on developing wellness products (seven), alongside research into pain, respiratory, and oral health products. In addition, the Haleon Shopper Science Lab conducted 65 research projects.

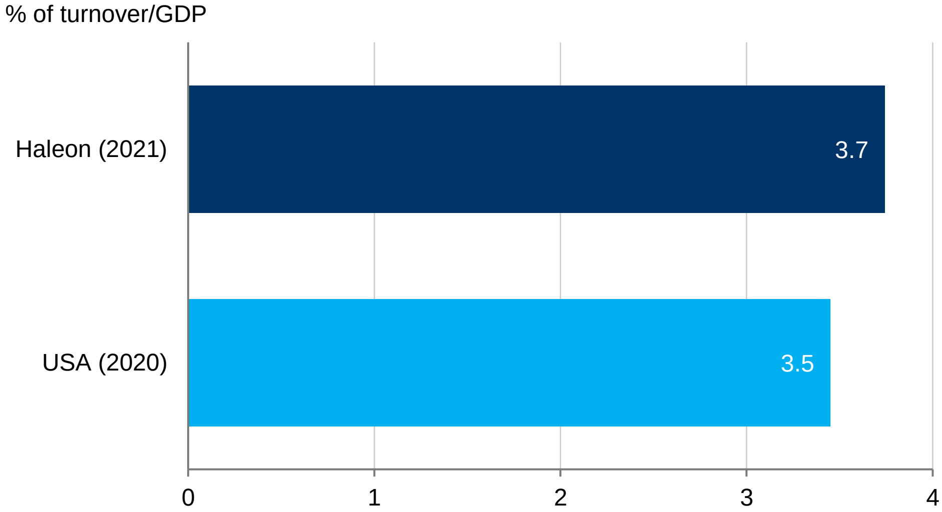
Haleon supported approximately 178 R&D jobs at its facility in Richmond, Virginia. R&D forms only part of Haleon's investments: overall, it made $33 million of capital expenditure across its operations in the USA in 2021.

[7] OECD, *Gross Domestic Spending on R&D*, Paris, 2022. https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm Note that this is the latest available data at the time of writing.

$154 million

Haleon's R&D spending in the USA in 2021.

Fig. 11. R&D investment, USA, 2021



Source: OECD, Haleon, Oxford Economics

R&D makes a difference to economic productivity in a number of ways: by improving the quality of goods, by reducing the costs of producing existing goods, and by increasing the range of goods or intermediate inputs available. Furthermore, R&D carried out in one company can have positive spill-overs to other firms or industries as the benefits accrue to competitors, other firms, suppliers and customers. In this way, R&D advances a nation's technological frontier, helping it to deliver greater economic output. Economic theory identifies various channels through which R&D spending contributes to economic growth in the long run. These include, but are not limited to:

- Stimulating private research;
- Creating a body of accessible knowledge;
- Training skilled graduates;
- Improving human capital and the ability to solve complex problems and develop ideas;
- Creating new scientific methodologies;
- Developing new instrumentation and equipment for the wider sector/industry;
- Forming informal networks through agglomeration;
- Improving economic interaction;
- Attracting greater investment and creating new firms; and
- Increasing domestic competition leading to lower prices and a more diverse set of products.

With R&D spending, the benefits to the economy arise initially from the general increase in spending—aggregate demand increases as research facilities are developed and researchers are deployed. The fruits of R&D-driven innovation are realised over time as new products and processes gradually enter the economy.

To estimate the quantitative relationship between Haleon's R&D spending and GDP gains, Oxford Economics' approach built upon the best practice in the literature and the latest available datasets.[8]

We find that Haleon's 2021 R&D spending generates a GDP boost to the USA economy of $57 million by 2031. The gains from R&D spending are therefore not limited to the sectors or products to which R&D spending is allocated. A large number of sectors benefit, both in the short term and the long term—these effects are called 'spillover' effects. We find that 78% of the GDP benefits are realised due to research in the manufacturing of chemical & pharmaceutical products, the sector within which consumer healthcare products are categorised.[9] The remaining 22% spill over to the rest of the economy as the benefits of innovation are spread widely.

$57 million

Productivity benefits of Haleon's R&D expenditure in the USA by 2031.

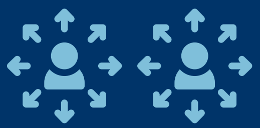
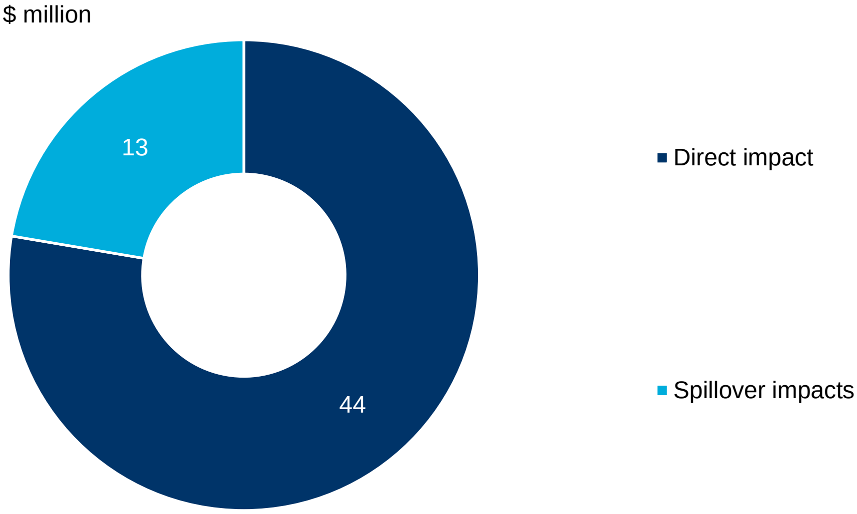


Fig. 12. Productivity benefits of R&D expenditure, USA, 2031



Source: Haleon, Oxford Economics. Note: may not sum due to rounding.

4.2 EXPORTS

Haleon also makes a positive contribution to USA exports. In 2021, it made $60 million of sales abroad, equivalent to 1.5% of turnover. Key export markets for Haleon products manufactured in the USA include Central America, and neighbouring Canada and Mexico. Collectively, these three markets account for more than two-thirds of Haleon's exports from the USA.

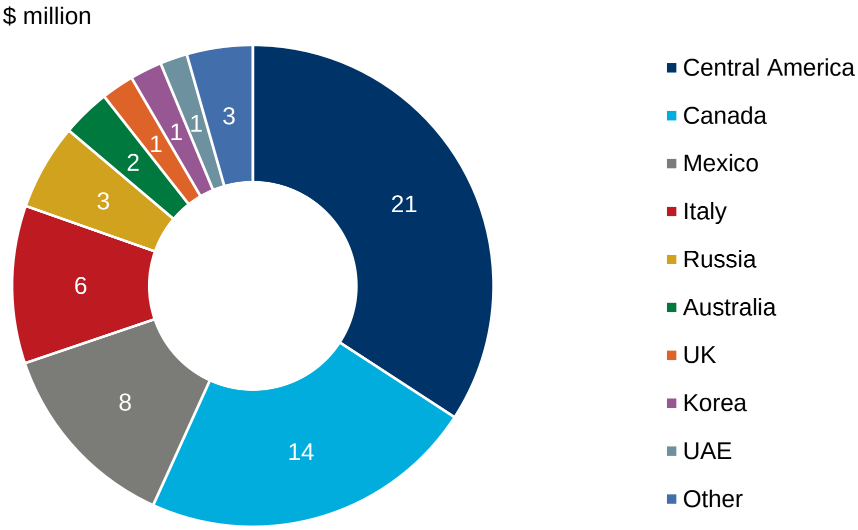
[8] See Appendix 1 for further detail.

[9] Note that this analysis considers the sector of 'output' of R&D spending, rather than the input (scientific research & development). The production of consumer healthcare goods sits within the manufacturing of chemicals & pharmaceutical products sector.

$60 million

Total exports of goods produced by Haleon in the USA in 2021.

Fig. 13. Haleon's exports by destination, USA, 2021



Source: Haleon, Oxford Economics. Note: may not sum due to rounding.

4.3 CHARITABLE DONATIONS

Haleon also contributes to American society through charitable donations. In 2021, Haleon made $674,000 in charitable donations across the USA.

A wide array of charities and not-for-profit organisations benefited from Haleon's charitable giving in the USA during 2021. Beneficiaries included United Way of North Jersey, the Big Brother & Big Sister program, The National Association for Child Development (NACD) Foundation, America's Grow-A-Row, Red Cross, UNC Health Foundation, NJ Nourish, and many others. Haleon also supported scholarships provided by the American Dental Education Association (ADEA), and the American College of Prosthodontists Education Foundation (ACPEF). These donations affirmed Haleon's commitment to community development across a range of activities including oral health, childhood development, food & nutritional security, and hygiene improvement.

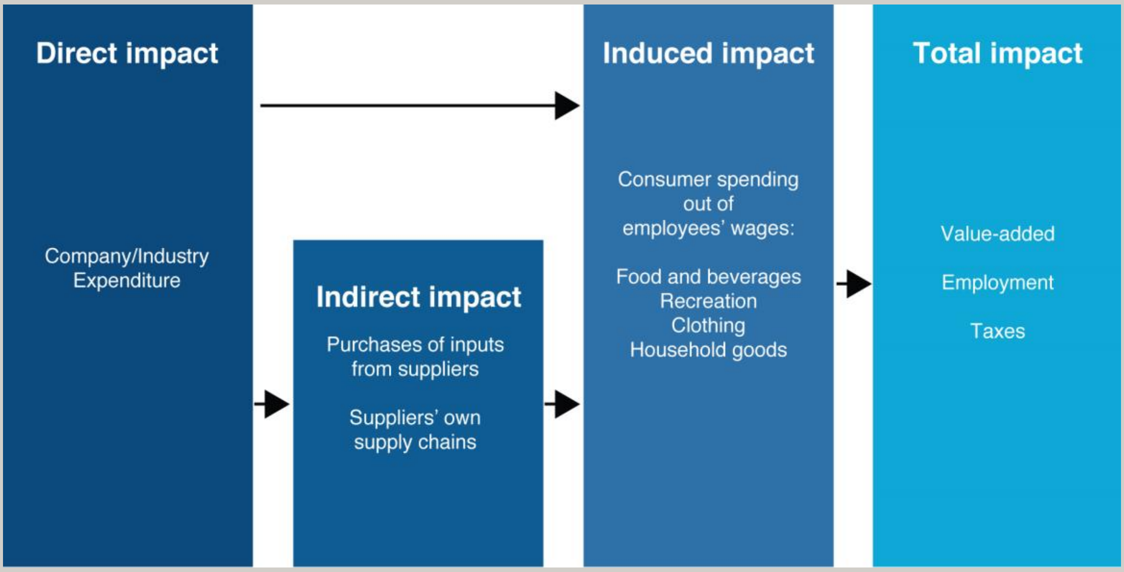
APPENDIX 1 TECHNICAL ANNEX

ECONOMIC IMPACT MODELLING

Economic impact modelling is a standard tool used to quantify the economic contribution of a firm or industry. Impact analysis traces the economic contribution through three separate channels:

- **Direct impact** refers to activity conducted directly by Haleon in the USA.
- **Indirect impact** consists of activity that is supported because of the procurement of goods and services by Haleon throughout the economy. It includes not just its purchases, but subsequent rounds of spending throughout the domestic supply chain.
- **Induced impact** reflects activity supported by the spending of wage income by direct and indirect employees.

Fig. 14. Direct, indirect, induced, and total economic impacts

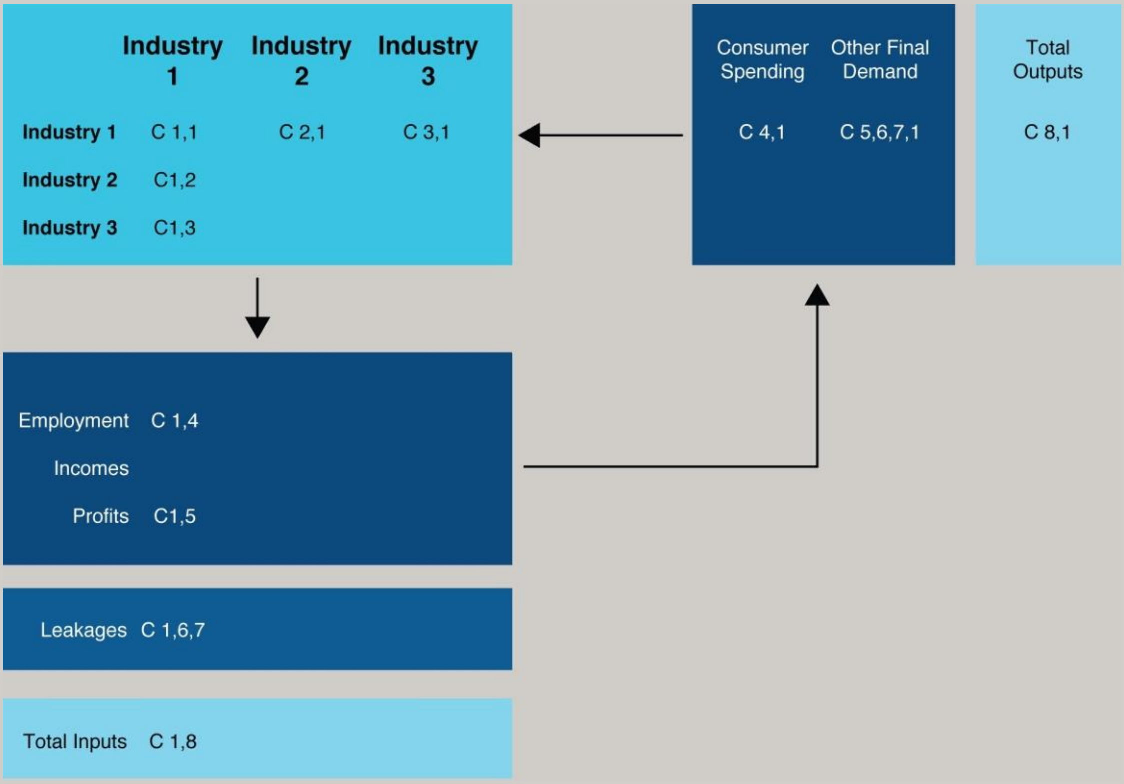


Data on the direct impacts were provided by Haleon.

Indirect and induced impacts were estimated using an input-output model. An input-output model gives a snapshot of an economy at any point in time. The model shows the major spending flows from final demand (i.e. consumer spending, government spending, investment, and exports to the rest of the world); intermediate spending patterns (i.e. what each sector buys from every other sector—the domestic supply chain in other words); how much of that spending stays within the economy; and the distribution of income between employment and other forms such as corporate profits. Input-output modelling for the United States was performed in IMPLAN, an industry-standard input-output modelling software package, which synthesises data from multiple US government sources to construct an integrated modelling framework built around the Bureau of Economic Analysis' input-output tables for the United States.[10] Fig. 15 below provides an illustrative guide to a stylised input-output model.

[10] https://implan.com/

Fig. 15. A stylised input-output model



PRODUCTIVITY MODEL

Our analysis investigated how R&D expenditure benefits not only the entities conducting the research, but also the economy more widely. This occurs as the knowledge gained via research spills over into the wider economy, through channels including sharing know-how with suppliers, customers benefiting from innovations, and staff turnover (including those leaving research institutions for other forms of employment). The channels through which innovation and R&D influence the wider economy are well-established in economic literature. The aim of our model was to update this analysis using the most recent and relevant datasets and evidence.

We developed an econometric model to explain how R&D expenditure in different sectors contributes to productivity growth. The boost to productivity identified by the model comes from both new innovations and from enhancing the skills of the labour force. The model includes two channels of benefits supported by this investment:

- those which accrue **directly** to the sector undertaking the research; and
- the **spillover** benefits generated as firms **in other sectors** of the economy apply the knowledge and innovations to help to develop new products and improve operational efficiency.

We begin this section with a description of the existing academic literature on the topic and how it informed our modelling approach, followed by a description of the dataset and the model specification. We conclude with a comparison of our results with other similar studies.

Literature review

A number of studies investigate the relationships between productivity-led economic growth and R&D spending. An extensive literature also exists on the topic of intra-country and inter-country industry spillovers of innovation and R&D influencing overall productivity.

To ensure that the most appropriate approach for our methodology was chosen, Oxford Economics reviewed papers that have modelled the direct effects as well as spillovers. This section discusses studies taking a macroeconomic approach to measuring Total Factor Productivity (TFP), (using national R&D data at the sector level that is readily available) instead of firm-level data.

Overall modelling approach

The modelling approach was adopted from Badinger and Egger (2008)[11] who adopted a spatial econometric approach to estimate intra-industry and inter-industry productivity spillovers in TFP (total factor productivity) transmitted through input-output relations in a sample of 13 OECD countries and 15 manufacturing industries. Our methodology follows a similar approach with a larger dataset with more countries and more recent data. To account for the spatial element, a spillover matrix is constructed using the latest Social Accounting Matrices for each country from the OECD, broadly following the approach in Coe, et al (2019)[12].

Explanatory variables

The choice of the other selected explanatory variables finds its motivation from the study by Coe, et al (2019), who studied the impact of domestic and foreign R&D on TFP. In particular, they included variables to control for human capital and other institutional variables (legal origin and patent protection) to allow for parameter heterogeneity based on a country's institutional characteristics. Hanel (1994)[13] also used patent information within the spatial matrix to measure the extent of spillovers in the economy.

Several other studies also emphasise controlling for human capital to measure the extent of R&D spillovers on TFP. For example, Engelbrecht (1996)[14] and del Barrio-Castro, *et al.* (2002)[15] use average years of schooling a measure of human capital to account for innovation outside the R&D sector.

Findings from previous studies

Various studies, e.g., Mairesse and Mohnen (1994)[16], Hall (2010), Guellec and van Pottelsberghe de la Potterie (2010)[17], found statistically significant relationships between R&D, including spillovers, and various measures of productivity.

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[11] Badinger, Harald, and Peter Egger, Intra-and inter-industry productivity spillovers in OECD manufacturing: A spatial econometric perspective, No. 2181. CESifo working paper, 2008.
[12] Coe, David T., Elhanan Helpman and Alexander W. Hoffmaister, *International R&D Spillovers and Institutions,* IMF Working Paper. WP/08/104.
[13] Hanel, Petr, R&D, Inter-industry and international spillovers of technology and the total factor productivity growth of manufacturing industries in Canada, 1974–1989, CERGE-EI Working Paper Series 73 (1994).
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[15] del Barrio-Castro, Tomás, Enrique López-Bazo, and Guadalupe Serrano-Domingo, *New evidence on international R&D spillovers, human capital and productivity in the OECD*, Economics Letters 77, no. 1 (2002): 41–45.
[16] Mairesse, Jacques, and Pierre Mohnen, *R&D and productivity growth: what have we learned from econometric studies*, In Eunetic Conference on Evolutionary Economics of Technological Change: Assessment of Results and New Frontiers, pp. 817–888. 1994.
[17] Guellec, D. and B. van Pottelsberghe de la Potterie (2001), *R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries*, OECD Science, Technology and Industry Working Papers, No. 2001/03, OECD Publishing, Paris. https://doi.org/10.1787/652870318341.

Some papers, such as Bournakis, et al (2018),[18] found that cross-industry differences. For example, Bournakis, et al (2018) found that high technology industries have benefitted more from R&D spillovers, mainly due to knowledge spillovers (as opposed to supply-chain effects).

In terms of qualitative conclusions our macroeconomic approach is in line with papers with microeconomic (firm-level) frameworks, such as Hall, B. et al (1996)[19].

Moretti, et al (2021)[20] is the most recent paper using a combination of macroeconomic and firm-level datasets to understand the impact of government R&D spending on privately funded R&D and TFP. They find that government R&D spending crowds in private R&D spending—a 10% increase in government R&D spending increases private R&D spending by 5%–6% in a sample of OECD countries. They find a one percentage point increase in the ratio of R&D spending to value-added TFP growth rates by 0.05–0.08 percentage points (implying GDP elasticity with respect to R&D spending of 0.12–0.20 over a 10-year period).

A comparison of the R&D elasticities[21] from various studies is shown in Fig. 19.

Specific learnings for our methodology

We combined the techniques in the existing literature covering spillovers, but our approach was adapted to capture inter-industry spillovers and direct effects separately. Our approach also accounted for various econometric issues which were explored in the existing academic literature such as: non-stationarity in Tsamadias et al (2019);[22] cointegration techniques in del Barrio-Castro (2002);[23] and R&D and productivity endogeneity in Bravo-Ortega and Marin (2011).[24]

Our approach also used a holistic selection of available explanatory variables discussed extensively in the papers above, thus mitigating the risk of omitted variable bias. We have also accounted for legal, institutional, R&D, and human capital factors in the analysis, and this examination presents the most up-to-date amalgam analysis of the topic.

Data used in our model

A panel dataset was constructed underpinned by a time series of R&D expenditure by sector across a range of countries. The dataset was sourced primarily from the OECD which documents R&D expenditure in member (and some non-member) states broken down by industry and characteristics, such as type of research (basic, experimental, applied), source of funds (public and private) and

[18] Bournakis, Ioannis, Dimitris Christopoulos and Sushanta Mallick, *Knowledge spillovers and output per worker: an industry-level analysis for OECD countries,* Economic Inquiry, 2017. https://doi.org/10.1111/ecin.12458
[19] Mairesse, Jacques, and Bronwyn H. Hall, Estimating the productivity of research and development: An exploration of GMM methods using data on French & United States manufacturing firms, NBER working paper w5501 (1996).
[20] Moretti, Enrico, Claudia Steinwender, and John Van Reenen, *The intellectual spoils of war? Defense R&D, productivity and international spillovers*, No. w26483. National Bureau of Economic Research, 2019.
[21] R&D elasticity, or the elasticity of GDP with respect to R&D, is defined as the percentage increase in GDP (relative to baseline GDP levels) associated with a 1% increase in R&D spending (relative to a baseline level of R&D spending).
[22] Tsamadias, Constantinos, Panagiotis Pegkas, Emmanuel Mamatzakis, and Christos Staikouras, *Does R&D, human capital and FDI matter for TFP in OECD countries?*, Economics of Innovation and New Technology 28, no. 4 (2019): 386–406.
[23] del Barrio-Castro, Tomás, Enrique López-Bazo, and Guadalupe Serrano-Domingo, *New evidence on international R&D spillovers, human capital and productivity in the OECD*, Economics Letters 77, no. 1 (2002): 41–45.
[24] Bravo-Ortega, Claudio, and Álvaro García Marín, *R&D and productivity: A two way avenue?,* World Development 39, no. 7 (2011): 1090–1107.

subject field. This granularity made it possible test how these characteristics influence the size and sectoral composition of productivity spillovers. Data on productivity (Total Factor Productivity) was sourced from EU KLEMS.[25]

The variables and sources are listed in the table below.

Fig. 16. Variables used in the productivity model

Variable	Data	Source
Total factor productivity	Total factor productivity, index: 2010 = 100[26]	EU KLEMS
	Total factor productivity, index: 2010 = 100	OECD Structural Analysis (STAN) database
Expected research and development, funded by the government sector and performed by private businesses	Government budget allocations for R&D	OECD Research and Development Statistics database
	Gross domestic expenditure on R&D by sector of performance and source of funds	OECD Research and Development Statistics database
	Domestic R&D paid for by the U.S. federal government and performed businesses, by funding agency and industry	National Science Foundation (US) Business Enterprise Research and Development Survey
Domestic spillover variable	Expected government funded research and development carried out by industries—weighted by the strength of industry linkage	OECD Country Input Output tables
Years of schooling in population	Average years of schooling in population	Oxford Economics' Global Economic Model
Strength of intellectual property rights	Protection of intellectual property rights score	Global Competitiveness Index 4.0, standardised by International Property Rights Index
Strength of patent protection	Patent protection score	Patent Rights Index, standardised by International Property Rights Index
Copyright Piracy	Copyright piracy score	BSA Global Software Survey; The Compliance Gap, standardised by International Property Rights Index
Ease of doing business score	Calculated ease of doing business score	World Bank - Ease of Doing Business survey
Public infrastructure	Public infrastructure expenditure as a % of GDP	OECD & International Transport Forum ITF Transport Outlook/OECD. Stat
Origins of legal system	Historical origins of legal system	Web searches

Source: Oxford Economics

Spillover variable

Productivity spillovers, which are the subject of this analysis, are supposed to take place mainly among firms. Since a large share of inter-firm trade is in intermediate goods, the SAM (social accounting matrices) is used to measure the extent and intensity of interactions both within and across industries.

[25] EU KLEMS is a dataset on measures of economic growth, productivity, employment, capital formation, and technological change at the industry level for a number of countries in Europe and elsewhere. For further details, see here: https://euklems.eu/.

[26] TFP is reported in statistical datasets as an index, reflecting the ratio of the output value relative to the value of inputs as of a particular base year. The base year defines the starting point of the dataset; however, a change in the base year would not change the underlying trend in the TFP data series.

The R&D spillover variable was calculated following the approach in Badinger and Egger (2008) [27] using OECD SAM data to capture the strength of inter-industry relationships. For example, if innovation leads to improved productivity in AI, then the technology goods manufacturing sector, which is a major supplier to growing AI businesses, will also benefit. Continuing with the same approach as in in Badinger and Egger (2008), the R&D spillover variable was calculated following the approach by taking the dot product of R&D spending and the weight matrix. Algebraically, this can be expressed as $R\&D\ spending_{\ i-1,t} = W \cdot R\&D\ spending_{\ i,t}$, where W is the inter-industry weight matrix created using the OECD SAM data as described above. We only modify the Badinger and Egger approach by removing within-sector interactions to avoid double counting the direct effect on sectors to which R&D spending is allocated (the direct effect is modelled separately for this study).

Modelling approach

A dynamic panel data econometric model was developed. To develop the model specification, a series of statistical tests were used to identify the correct specification and functional form for the model. The importance of this step was to ensure that the resulting model was statistically robust with unbiased estimates of relationships.

Specifically, starting with a large pool of candidate explanatory variables, the LASSO (least absolute shrinkage and selection operator) method was used which made it possible to identify a more parsimonious model with fewer explanatory variables. Using a statistical method— like LASSO— instead of manually examining the variables reduces the risk of error due to human bias or judgement.

Next, the Wooldridge test for serial correlation was used to ascertain whether there were neglected dynamics in the model worth accounting for. Based on the results from the Wooldridge test, a dynamic model specification was found to be more optimal in capturing key features of the outcome variable (i.e., productivity).

Following the Wooldridge test, another diagnostic test was run to ascertain whether the key explanatory variables used in the parsimonious model can be treated as exogenous. Based, on the results of this test, it can be concluded that the explanatory variables considered can all be treated as exogenous.

Based on the statistical results of all the pre-estimation tests, the model was estimated using the bias corrected LSDVC (least square dummy variable) estimator, where the chosen estimator is the Arellano-Bond estimator.

Finally, the results model passed the Nickell Bias test which is a key statistical test for model robustness.

Further details on the robustness tests and the test results are shown on p.24.

[27] Badinger, Harald, and Peter Egger, Intra-and inter-industry productivity spillovers in OECD manufacturing: A spatial econometric perspective, No. 2181. CESifo working paper, 2008.

STATISTICAL ROBUSTNESS TESTS

Wooldridge test

This test was used to ascertain whether if there was no first-order autocorrelation in the model residuals. The presence of autocorrelation in the residuals signalled the presence of neglected dynamics in the model that ought to be accounted for.

One way to account for such dynamics was to adopt a dynamic model specification. The p-value for this test was 0.000, this meant that the null hypothesis of no first-order autocorrelation was rejected.

Nickell bias

Monte Carlo simulation revealed that estimating a dynamic model using a pooled OLS or Fixed Effect (FE) model results in a bias in the coefficient of the lagged dependent variable.

Specifically, for the pooled OLS estimator, this bias is upward whilst for the FE model, the bias is downward. Hence the correct coefficient ought to be somewhere between the latter two coefficients.

Indeed, the model passed the Nickell bias test given that the coefficient on the lagged productivity is 0.669, this was smaller than the coefficient from the OLS model which was 0.944 and bigger than the one from the FE model; 0.526.

Endogeneity test

A separate diagnostic check also tested for the hypotheses of whether each of the explanatory variable used in the model can be treated as exogenous. The test results indicated that all the variables, except for the lagged productivity variable, can be treated as exogenous.

Fig. 17. Endogeneity test results

Variables	Endogeneity test	Hansen instrument validity test	Result interpretation
1^{st} lag of research and development—direct	P-value=0.15 (no endogeneity)	P-value=0.55 (valid instruments)	Exogenous
2^{nd} lag of research and development—indirect	P value=0.41 (no endogeneity)	P-value=0.48 (valid instruments)	Exogenous
1^{st} lag of change in average schooling	P value=0.24 (no endogeneity)	P-value=0.05 (valid instruments)	Exogenous
1^{st} lag of patent protection	P-value=0.14 (no endogeneity)	P-value=0.07 (valid instruments)	Exogenous

Source: Oxford Economics

The preferred model specification developed using the modelling approach described above was as follows:

$$TFP_{i,t} = \beta_1 TFP_{i,t-1} + \beta_2 R\&D\ spending_{i,t-1} + \beta_3 R\&D\ spending_{i-1,t-2} + other\ control\ variables$$

where, the dependent variable, $TFP_{i,t}$ indicates the productivity in sector i at year t, $TFP_{i,t-1}$ corresponds to the previous year's value, $R\&D\ spending_{i,t-1}$ indicates the R&D spending in in sector i

in the previous year, $R\&D\ spending_{i-1,t-2}$ indicates R&D spending in the rest of the economy (i.e., excluding sector i).

The model specification was extensively tested to identify if quadratic or higher polynomials of the R&D spending variable should be included, but these tests did not provide any basis for their inclusion. Similarly, various lag lengths were also tested, but provided no statistical basis for their inclusion.

Control variables included patent protection, average years of schooling and a time trend. As discussed above, the LASSO approach meant that other control variables (listed in Fig. 16 above) were not found to be statistically significant. A time trend was also included to isolate the impact of trending elements on the explanatory variables. In other words, some variables trend up with time and this may lead the model to falsely conclude that they are correlated. This risk is mitigated through the introduction of a time trend variable.

Discussion of results

The estimated model results and coefficients are shown in the table below.

Fig. 18. Productivity model: econometric results

Productivity	Coefficient	Standard error	Z value	P value	Lower bound	Upper bound
Productivity lag	0.671	0.03	19.51	0.00	0.600	0.740
R&D spending (first lag)	0.002	0.001	1.85	0.06	0.000	0.004
R&D spillovers (second lag)	0.008	0.01	0.72	0.01	0.001	0.016
Average schooling	3.745	1.49	2.51	0.01	0.819	6.670
Patent protection	0.072	0.04	1.76	0.08	-0.008	0.153
Time trend	0.008	0.002	4.39	0.00	0.004	0.011

Source: Oxford Economics

The coefficients estimates are in line with expectation in both their magnitudes and signs. Both the direct and indirect impacts of real R&D spending on productivity are positive and statistically significant.

Specifically, in relation to the direct impact, there is a one-year lag between an initial investment in R&D and its subsequent effect on productivity, whilst for the indirect impact, a two-year lag length is observed.

Note that R&D spending generates some short-term demand-side gains (building new research facilities, consumer spending by newly hired researchers, etc.). Further, there are short-term supply-side gains (new research facilities helps various industries focus and optimise their efforts), and eventual long-term supply-side innovation-led gains (new processes, products, etc.). The model captures all these effects together but does not allow for them to be separated. In other words, it is not possible to identify when the innovation-led gains leading to new products or processes begin to be realised. The model only implies that GDP gains are observed within the sector in a year's time and in the wider economy in two years.

In relation to the relative size of the effects, the results indicate that a ten percent increase in the one-year lagged real R&D spending is associated with a 0.2% increase in returns on inputs measured using GDP. The indirect effects are relatively larger, with a ten percent increase in the two-year lagged real R&D spending associated with a 0.8% increase in average productivity.

It is reiterated that different lag lengths and higher polynomials of R&D spending were tested in the model and were found to be statistically insignificant.

Benchmarking the findings

The implied productivity elasticities with respect to GDP (i.e., the percent increase in TFP per 1% increase in R&D spending) from this analysis is roughly comparable to estimates from other studies, if slightly on the higher side.

Fig. 19. Comparison with R&D elasticities in other studies

Study	Elasticities	Study geography
Blanco, et al (2013)[28]	0.06–0.14	United States
Moretti, et al (2021)[29]	0.12–0.24	OECD countries
Guellec and van Pottelsbergh de la Potterie (2001)[30]	0.13–0.17	OECD countries
Bravo-Ortega and Marin (2011)[31]	0.16–0.17	65 OECD and European countries
Zachariadis (2004)[32]	0.17–0.38	OECD
Gumus and Celikay (2015)[33]	0.44–0.98	52 OECD and European countries
Oxford Economics	0.20–0.80	OECD countries

[28] Blanco, Luisa R., Ji Gu, and James E. Prieger, *The impact of research and development on economic growth and productivity in the US states*, Southern Economic Journal 82, no. 3 (2016): 914–934.
[29] Moretti, Enrico, Claudia Steinwender, and John Van Reenen, *The intellectual spoils of war? Defense R&D, productivity and international spillovers,* No. w26483. National Bureau of Economic Research, 2019.
[30] Guellec, D. and B. van Pottelsberghe de la Potterie (2001), *R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries*, OECD Science, Technology and Industry Working Papers, No. 2001/03, OECD Publishing, Paris, https://doi.org/10.1787/652870318341.
[31] Bravo-Ortega, Claudio, and Álvaro García Marín, *R&D and productivity: A two way avenue?*, World Development 39, no. 7 (2011): 1090–1107.
[32] Zachariadis, Marios, *R&D-induced Growth in the OECD?*, Review of Development Economics 8, no. 3 (2004): 423–439.
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