INTERNATIONAL MONETARY FUND

Productivity Shocks to the Pharmaceutical Sector and the Danish Economy

Denmark

Takuji Komatsuzaki

SIP/2024/043

***IMF Selected Issues Papers* are prepared by IMF staff as background documentation for periodic consultations with member countries.** It is based on the information available at the time it was completed on August 22, 2024. This paper is also published separately as IMF Country Report No 24/293.

2024
DEC

SELECTED ISSUES PAPER

© 2024 International Monetary Fund SIP/2024/043

IMF Selected Issues Paper
European Department

Productivity Shocks to the Pharmaceutical Sector and the Danish Economy

Prepared by Takuji Komatsuzaki

Authorized for distribution by Kotaro Ishi
December 2024

***IMF Selected Issues Papers* are prepared by IMF staff as background documentation for periodic consultations with member countries.** It is based on the information available at the time it was completed on August 22, 2024. This paper is also published separately as IMF Country Report No 24/293.

ABSTRACT: The pharmaceutical industry in Denmark has grown rapidly in recent years. This paper discusses the macroeconomic impact of the pharmaceutical sector. The analysis focuses on Novo Nordisk, the leading pharmaceutical company in Denmark, and its productivity impact on the rest of the economy. Empirical evidence suggests only weak correlations between productivity shocks at Novo Nordisk and overall economic growth, as well as between Novo Nordisk's productivity and that of other firms. However, we find evidence of a significant within-industry spillover effect in the pharmaceutical sector.

RECOMMENDED CITATION: Komatsuzaki, Takuji. Productivity Shocks to the Pharmaceutical Sector and the Danish Economy. IMF Selected Issues Paper (SIP/2024/043). Washington, D.C.: International Monetary Fund.

JEL Classification Numbers:	E23, O47
Keywords:	Productivity, spillovers, pharmaceutical.
Author's E-Mail Address:	tkomatsuzaki@imf.org

SELECTED ISSUES PAPERS

Productivity Shocks to the Pharmaceutical Sector and the Danish Economy

Denmark

INTERNATIONAL MONETARY FUND

DENMARK

SELECTED ISSUES

August 22, 2024

Approved By
European Department

Prepared by Takuji Komatsuzaki.

CONTENTS

PRODUCTIVITY SHOCKS TO THE PHARMACEUTICAL SECTOR AND THE DANISH ECONOMY 2

A. Introduction 2

B. Danish Pharmaceutical Sector and the Macroeconomy 4

C. Empirics: Shocks to Novo Nordisk and MNEs and their Impact on the Danish Economy 6

D. Conclusions 10

BOX

1. Danish Exports that Do Not Cross Border 3

FIGURES

1. Selected Indicators for Good Exports and Pharmaceutical Industry 3
2. Novo Nordisk: Selected Indicators 4
3. Macroeconomic Impact of the Pharmaceutical Industry 5

TABLES

1. Top-10 Firms in Denmark by Sales, 1995 and 2022 7
2. Regression Results: Impact of Firm-Specific Shocks on Real GDP Growth 8
3. Regression Results: Impact of Firm-Specific Shocks to the Smaller Firms 9

References 13

ANNEX

I. Technical Details 11

PRODUCTIVITY SHOCKS TO THE PHARMACEUTICAL SECTOR AND THE DANISH ECONOMY[1]

The pharmaceutical industry in Denmark has grown rapidly in recent years. This chapter discusses the macroeconomic impact of the pharmaceutical sector. The analysis focuses on Novo Nordisk, the leading pharmaceutical company in Denmark, and its productivity impact on the rest of the economy. Empirical evidence suggests only weak correlations between productivity shocks at Novo Nordisk and overall economic growth, as well as between Novo Nordisk's productivity and that of other firms. However, we find evidence of a significant within-industry spillover effect in the pharmaceutical sector.

A. Introduction

1. The pharmaceutical industry in Denmark has grown at a rapid pace in recent years. Since 2005, the real gross value added (GVA) of pharmaceuticals has increased sixfold (Figure 1). This extraordinary surge in real GVA over the past two years reflects increased export demand for new weight-loss drugs developed by Novo Nordisk, Denmark's leading pharmaceutical company.

2. To assess the implications of the pharmaceutical booms on the Danish macroeconomy, two structural characteristics are worth highlighting.

- First, Danish large multinational enterprises (MNEs) have become increasingly reliant on "merchanting and processing (M&P)," as evidenced by the increased exports that never cross Danish borders (Box 1). In the pharmaceutical sector, the bulk of the value of the drugs is attributable to the intellectual property embedded in them, and pharmaceutical companies use contract manufacturers abroad for production.

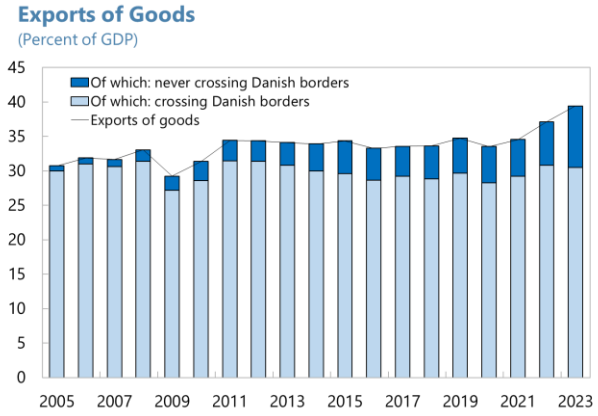
- Second, the expansion of the pharmaceutical sector has been mainly driven by a significant increase in labor productivity. The level of labor productivity in the pharmaceutical sector has increased more than threefold since 2005, compared to a 20 percent increase for all industries (Figure 1).

3. Against this backdrop, exploring how productivity shocks in the pharmaceutical industry have impacted Denmark's economic growth presents an interesting question. A priori, it is not clear to what extent strong productivity growth in the pharmaceutical sector, which substantially relies on foreign production, would boost overall Danish economic growth. Therefore, we first establish the quantitative relationship between productivity shocks at pharmaceutical companies and the real GDP growth. In this light, our analysis also more broadly covers large Danish MNEs using M&P. Next, we turn to the microfoundation of the relationship by investigating if productivity shocks in a dominant firm like Novo Nordisk have spillover effects to other firms, both

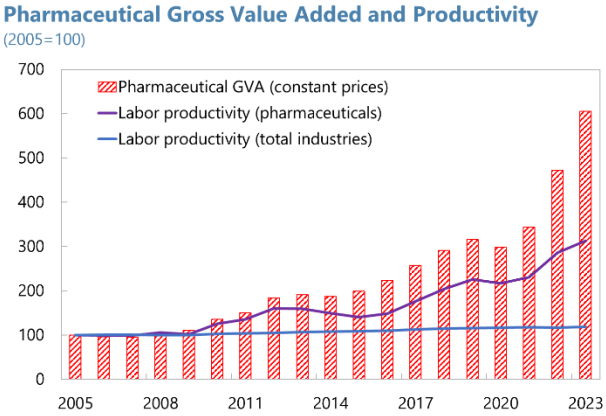
[1] Prepared by Takuji Komatsuzaki with support from Fuda Jiang (all EUR) and useful inputs from the IMF's Statistics Department. The authors thank participants of the workshop held at the Danmarks Nationalbank for useful discussions and comments.

within and outside the pharmaceutical industry. We address these questions empirically using firm-level data in Denmark.

Figure 1. Selected Indicators for Good Exports and Pharmaceutical Industry



Sources: Statistics Denmark, Haver Analytics, and IMF staff calculations



Sources: Statistics Denmark, Haver Analytics, and IMF staff calculations

4. The rest of this chapter is organized as follows. Section B briefly summarizes the stylized facts related to the Danish pharmaceutical sector and the macroeconomy. Section C presents the empirical models and results. Section D concludes.

Box 1. Danish Exports that Do Not Cross Border[1]

As illustrated in the main text, Danish companies' exports that do not cross border are becoming increasingly important. The exports from Danish companies' production abroad are classified into merchanting and processing, depending on whether they own the intermediate inputs. In both cases, the exports from the foreign production are counted as the Danish exports in the Balance of Payment Statistics although the goods never cross the Danish border.[2] Processing by large manufacturers (including pharmaceuticals) drive the trend increase in the foreign production.

Increases in the foreign production warrant attention in interpreting aggregate statistics.

- Foreign production combines factor inputs from Denmark and from the country where the production takes place. Danish factor inputs are heavier in intangible assets (intellectual property rights, sales expertise, etc.) and lighter in labor.
- As a result, foreign production has higher labor productivity and lower employee compensation.
- Increases in foreign production suggest that the labor productivity growth at the national aggregate level may not necessarily reflect labor productivity growth in the domestic economy, and that the output gap based on aggregate output may overstate capacity pressures in the labor market.

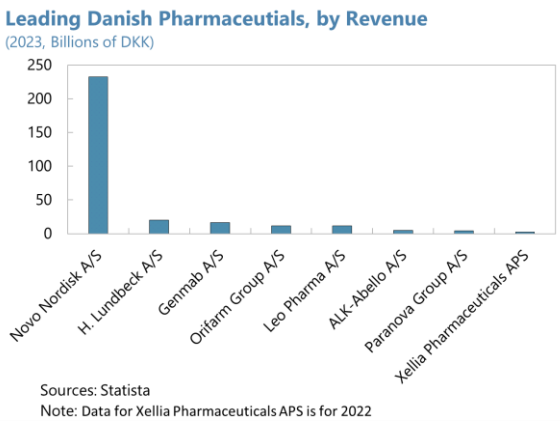
[1] This box draws on Productivity Board (2024a), Productivity Board (2024b), and Statistics Denmark (2019).

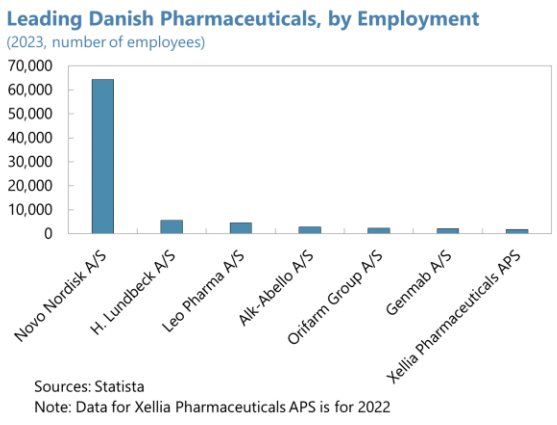
[2] If the goods produced by the Danish companies abroad are sold in Denmark, the sale is recorded as final consumption. This accounts for a small share of total foreign production, however.

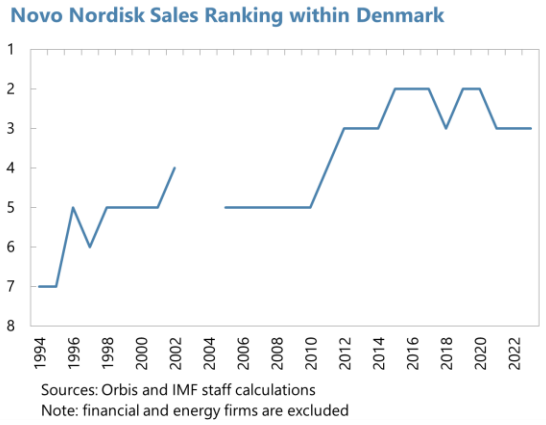
B. Danish Pharmaceutical Sector and the Macroeconomy

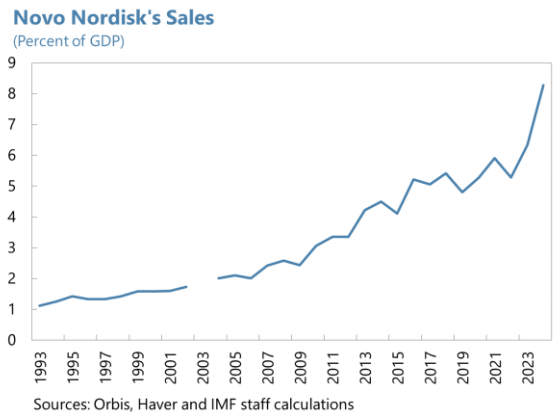
5. Denmark has a strong pharmaceutical industry. Novo Nordisk stands as the largest pharmaceutical company in Denmark and ranks among the top 20 largest pharmaceutical companies globally by revenue. It is a dominant company in the pharmaceutical industry, whether measured by sales or employment (Figure 2). For decades, Novo Nordisk has been one of Denmark's largest companies in Denmark, ranking in the top ten for sales among all Danish companies. Its presence has grown over time, especially rapidly in the last few years, with its sales as a share of Denmark's GDP increasing from 1 percent in the early 1990s to 8.3 percent in 2023.[2] A surge in foreign demand for its new drugs for diabetes and obesity is behind its exceptional growth in recent years. To meet the strong demand, Novo Nordisk is expanding its production capacity both in Denmark and abroad.

Figure 2. Novo Nordisk: Selected Indicators









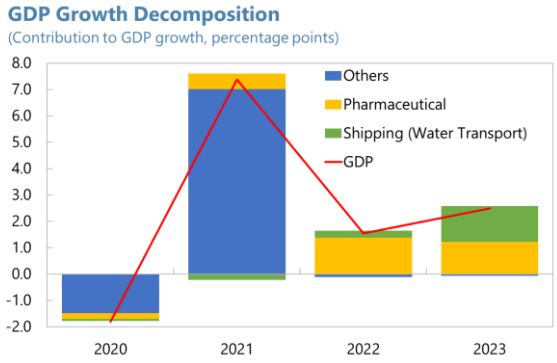
[2] Despite its recent growth, relative size of Novo Nordisk is not comparable to that of Nokia in Finland in the 2000s. In 2003, Nokia's sales were 26 percent of Finland's GDP (Gabaix 2011).

6. The pharmaceutical industry has increased its contributions to the growth of real GDP and exports and, to a lesser extent, corporate income taxes; however, its impact on employment has been relatively limited (Figure 3).

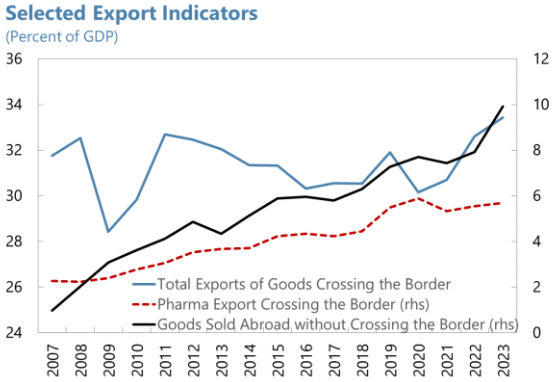
- *Real GDP growth* (top left chart). The growth decomposition highlights the extraordinary contribution of the pharmaceutical sector in 2022 and 2023. The pharmaceutical sector contributed about 10 percent to real GDP growth during 2020–21, with its contributions surging to 90 percent and 50 percent in 2022 and 2023, respectively.

- *Exports* (top right chart). A rapid growth in exports by the pharmaceutical sector is evident. Danish exports, originating from Denmark, have fluctuated around 29–33 percent of GDP over the past 15 years (blue line). Meanwhile, pharmaceutical exports have increased steadily from around 2 percent of GDP to 6 percent of GDP since 2007 (red dotted line). Exports not crossing the border (Box 1) have grown even faster, increasing from about 1 percent of GDP to about 10 percent of GDP (black solid line).

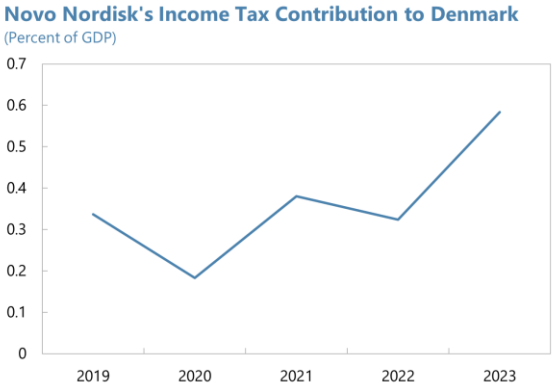
Figure 3. Macroeconomic Impact of the Pharmaceutical Industry



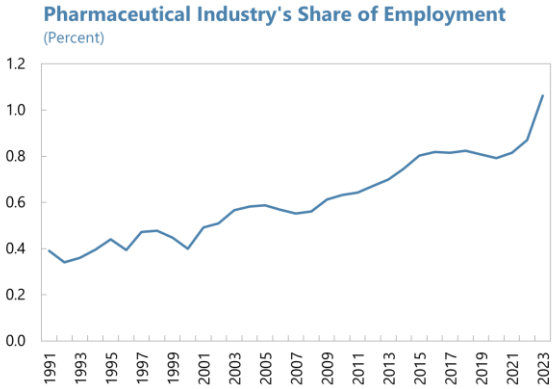
Sources: Statistics Denmark, Danmarks Nationalbank, Haver Analytics, and Fund staff estimates



Sources: Statistics Denmark and IMF staff calculations



Sources: Novo Nordisk Annual Reports and IMF staff calculations



Sources: Statistics Denmark and IMF staff calculations

- *Tax Revenue* (bottom left chart). Corporate income tax payments by Novo Nordisk to the Danish government has doubled in the last 5 years, increasing from about 0.3 percent of GDP in 2019 to 0.6 percent of GDP in 2023.

- *Employment* (bottom right chart). The share of employment in the pharmaceutical industry has shown a long-term increasing trend, yet the level of employment remains relatively low. This is attributed to the industry's heavy reliance on knowledge and the fact that a significant portion of production takes place abroad. Consequently, its contribution to domestic employment is smaller than its contribution to value-added (Box 1). The pharmaceutical industry accounts for 6.7 percent of nominal value added, while its share in employment is around 1 percent.

C. Empirics: Shocks to Novo Nordisk and MNEs and their Impact on the Danish Economy

7. Two sets of regressions are run using firm-level data. The first set estimates the impact of labor productivity shocks at Novo Nordisk and other MNEs on the real GDP growth. The second set of regressions assesses the spillover effects of labor productivity from Novo Nordisk to other firms within the country. The data source is Orbis, a worldwide database that includes firm-level income statements and balance sheets for both listed and unlisted companies. The first set of regressions spans from 1993 to 2022, while the second set covers 1995 to 2022, both at annual frequencies. The coverage period for the second set is shorter due to the need to have sufficient number of companies in the dataset.[3]

How Much Have Shocks to Novo Nordisk and Other MNEs Impacted Denmark's Real GDP Growth?

8. The regression specification is as follows:

$$ln(GDP_t) - ln(GDP_{t-1}) = \alpha + \beta_1 ScaledShocks_t + \beta_2 ScaledShocks_{t-1} + \beta_3 ScaledShocks_{t-2} + \varepsilon_t$$

Where real GDP growth is regressed on ScaledShocks and their lags. Estimation methodology is OLS and ε_t represents residuals. The specification follows Gabaix (2011), which proposes that idiosyncratic firm-level shocks can explain an important part of movements in the aggregate economy when the firm is sufficiently large. ScaledShocks is size-weighted, firm-specific labor productivity shocks. These are constructed as follows:

(i) Calculate firm-level labor productivity growth as annual changes in sales per employee.

$$\text{ProductivityGrowth}_{j,t} = \ln\left(\frac{\text{Sales}_{j,t}}{\text{Employees}_{m,t}}\right) - \ln\left(\frac{\text{Sales}_{j,t-1}}{\text{Employees}_{m,t-1}}\right)$$

[3] The number of companies in the dataset exceeds 100 in 1995. The number of companies increases over time, exceeding 2000 in 2012 and 4000 in 2017.

(ii) De-mean the firm-level labor productivity growth to remove the economy-wide effect to derive firm-specific labor productivity shocks.

$$ProductivityShocks_{j,t} = ProductivityGrowth_{j,t} - \frac{1}{N}\sum_{j=1}^{N} ProductivityGrowth_{j,t}$$

(iii) Scale the firm-specific labor productivity shocks by the size of the firm measured by sales.

$$ScaledShocks_{j,t} = \frac{Sales_{j,t-1}}{GDP_{t-1}} ProductivityShocks_{j,t}$$

9. Two types of firm-level productivity shocks are considered. The first is related to Novo Nordisk. The second type of labor productivity shock is calculated as cumulative firm-specific labor productivity shocks to the largest firms, aimed at broadly capturing the shocks to large MNEs. These shocks are constructed by aggregating ScaledShock of the top-10 firms each year. Table 1 lists the top-10 firms in selected years.

Table 1. Denmark: Top-10 Firms in Denmark by Sales, 1995 and 2022

	1995		2022	
Rank	Name	Industry	Name	Industry
1	Lauritzen Fonden Holding ApS	Transporting and storage	A.P. Moller- Maersk A/S	Admin. and support service
2	Aktieselskabet Potagua	W and R trade	Maersk A/S	Transport and storage
3	FLSmidth & Co. A/S	Manufacturing	Novo Nordisk A/S	Manufacturing
4	ISS A/S	Admin. and support service	Energi Danmark A/S	Electricity, gas, steam air conditioning supply
5	Novo Nordisk A/S	Manufacturing	Vestas Wind Systems A/S	Professional, scientific and technical activities/ Manufacturing
6	Carlsberg A/S	Manufacturing	Orsted A/S	Electricity, gas, steam air conditioning supply
7	Berendsen A/S	Other services activities	ISS A/S	Admin. and support service activities
8	Dupont Nutrition Biosciences ApS	Manufacturing	Selfinvest ApS	W and R trade
9	Arla Foods Amba	Manufacturing	Carlsberg A/S	Manufacturing
10	Monberg & Thorsen A/S	Construction	Salling Group A/S	W and R trade

Source: Orbis and the Danish authorities.
Note: Financial and energy firms are excluded, following the literature. Exact industries excluded follow Jannati (2020).

10. The regression results are presented in Table 2.

- We found weak evidence that Novo Nordisk's productivity shock is positively associated with GDP growth (Column 1). The estimated coefficients for ScaledShocks for the first and second lags are positive, with the latter being statistically significant at the 10 percent level.

- We found stronger evidence that the productivity shock to the top-10 MNEs and economic growth are positively associated (Column 2). Coefficients for ScaledShocks are positive both contemporaneously (at the 5 percent significance level) and for the second lag (at the 10 percent significance level). Using the Sales-to-GDP ratio of the top-10 MNEs for 2021, the estimated model suggests that a 1.85 percent increase in the labor productivity were associated with a 0.3 percentage points increase in real GDP growth on average during 1993–2022.[4]

11. The weak statistical evidence related to Novo Nordisk's productivity shock (Column 1) may be attributed to limited data. It should be noted that Novo Nordisk was considerably smaller in size during the earlier part of the sample period. As Novo Nordisk continues to grow and more data accumulates, we may detect stronger statistical associations between Novo Nordisk's productivity shocks and economic growth, similar to what was found for the top-10 MNEs.

Table 2. Denmark: Regression Results: Impact of Firm-Specific Shocks on Real GDP Growth

	(1) Real GDP growth	(2) Real GDP Growth
ScaledShocks(Novo)$_t$	-0.00795	
	(-0.53)	
ScaledShocks(Novo)$_{t-1}$	0.0113	
	(0.92)	
ScaledShocks(Novo)$_{t-2}$	0.0236*	
	(1.75)	
ScaledShocks(Top 10)$_t$		0.00336**
		(2.53)
ScaledShocks(Top 10)$_{t-1}$		-0.0000102
		(-0.00)
ScaledShocks(Top 10)$_{t-2}$		0.00365*
		(1.87)
Constant	1.704***	1.819***
	(3.61)	(5.15)
N	25	30
R^2	0.169	0.201

Note: t statistics in parentheses, * p<0.1, ** p<0.05, *** p<0.01.

Does the Shock to Novo Nordisk Have Spillovers to Other Firms?

12. The regression specification is as follows:

[4] See Annex for more detailed explanation.

$$ScaledShocks(Other)_{j,t} = \alpha_j + \beta_1 ScaledShocks(Novo)_{i,t-1} + \beta_2 ScaledShocks(Novo)_{i,t-1} * P_dummy + \beta_3 X_{j,t-1} + \varepsilon_{j,t}$$

ScaledShocks(Other) refers to the level of size-weighted, firm-specific labor productivity shocks for non-top 10 companies (as defined in paragraph 6). This variable is regressed on Novo Nordisk's productivity shock (identical to Novo Nordisk's productivity shocks in the previous regression) and firm-level control variables in the previous year, together with firm-fixed effects. The specification follows Jannati (2020), which estimates geographical spillovers of productivity shocks from dominant companies in the U.S. to the smaller firms that are geographically close to them. The firm-level control variables ($X_{j,t-1}$) include the firms' lagged firm-specific labor productivity shocks, cash flows, leverage, loss, and size (see Annex for precise definition of the variables). In the extension of this basic specification, the interaction of the Novo Nordisk firm-specific shock and the pharmaceutical industry dummy (P_dummy) is added to estimate the additional spillover impact of being in the same industry as Novo Nordisk ("within-industry effects").

Table 3. Denmark: Regression Results: Impact of Firm-Specific Shocks to the Smaller Firms[1]

	(1) ScaledShocks(Other)$_t$	(2) ScaledShocks(Other)$_t$
ScaledShocks(Novo)$_{t-1}$	0.000339	0.000259
	(1.11)	(0.82)
ScaledShocks(Novo)$_{t-1}$*		0.00962**
P_Dummy		(2.30)
Constant	1.022	1.009
	(0.81)	(0.80)
N	7745	7745
R^2		

Note: t statistics in parentheses, * p<0.1, ** p<0.05, *** p<0.01.
[1] Coefficients for the firm-level control variables (X) is omitted from the table to economize on space. The full regression table is shown in the Annex.

13. The empirical analysis suggests that the spillover effect on the broader economy is small and uncertain, while the within-industry spillover effect is strong (Table 3).[5]

- Correlations between Novo Nordisk's productivity shocks and those of other firms are found to be quite weak. The estimated coefficient is positive but small (0.0003) and not statistically significant (Column 1). This indicates limited and uncertain spillover effects on the broader economy.

- A model in Column 2 includes the interaction term. Consistent with Column 1, the estimated coefficient of Novo Nordisk's productivity shock is small (0.0003) and not statistically significant.

[5] See Annex for more detailed explanation.

However, the estimated coefficient for the interaction term is positive (0.009) and statistically significant at the 5 percent level.

- Using the size of the companies in 2022, the estimates suggest that, on average, a one percentage point increase in labor productivity of Novo Nordisk was associated with a 0.75 percentage point increase in labor productivity of other pharma companies. The strong within industry spillover effects may provide some evidence that Novo Nordisk's R&D activities have externality effects within the pharmaceutical industry.

D. Conclusions

14. The pharmaceutical industry has substantial and increasing influence on the Danish economy. Its contribution to real GDP growth has been extraordinary over the past two years, and it significantly contributes to exports. Employment in the pharmaceutical sector remains low, while its contributions to tax revenues have increased from low levels.

15. Empirical evidence is mixed. The analysis suggests that productivity shocks at Novo Nordisk and Denmark's overall economic growth appear to be positively correlated, albeit with lags, but the evidence is relatively weak. This may be due to a lack of sufficient data, considering that we found stronger evidence of positive correlations between the top-10 MNEs and Denmark's GDP. While the spillover effect of Novo Nordisk's productivity on the broader economy is small and uncertain, there is a strong within-industry spillover effect in the pharmaceutical sector.

16. These findings suggest there is limited risk that Denmark's booming pharmaceutical company would become its "Nokia." Although the pharmaceutical sector will be a key driver of growth, most of its production occurs overseas under Danish ownership. As a result, its linkages with the rest of the domestic economy, in terms of employment and supply chains, are somewhat limited. The empirical results also indicate limited spillover effects through productivity channels. However, the empirical results may underestimate the influence of Novo Nordisk due to limited data.

Annex I. Technical Details

A. Interpretation of Regression Coefficients

The regression coefficient in (2) in Table 2 suggests that 100 units increase in ScaledShocks(Top 10)t is associated with 0.34 percentage point increase in real GDP growth. Recall that

$$ScaledShocks(Top\ 10)_t = \sum_{j=1}^{10} \frac{Sales_{j,t-1}}{GDP_{t-1}} ProductivityShocks_{j,t}$$

In 2021, sum of top-10 firms' sales was 54 percent of GDP. Assuming the top-10 firms have the same level of productivity shocks in 2021 for simplification, 100 units increase in ScaledShocks(Top 10)t translates to 1.85 percent increase in labor productivity. As a result, 1.85 percent increase in labor productivity by top 10 firms is associated with 0.34 percentage point increase in real GDP growth.

The regression coefficient for Novo Nordisk firm-specific shock in (1) in Table 4 suggests that one unit increase in weighted Novo Nordisk labor productivity shock leads to 0.0003 unit increase in weighted "other firms" shock, statistical significance issue aside. Therefore:

$$\Delta ScaledShocks(Other)_t = 0.0003 \Delta ScaledShocks(Novo)_t$$

Recall that

$$ScaledShocks(Novo)_t = \frac{Sales_{Novo,t-1}}{GDP_{t-1}} ProductivityShocks_{Novo,t}$$

$$ScaledShocks(Other)_t = \frac{Sales_{Other,t-1}}{GDP_{t-1}} ProductivityShocks_{Other,t}$$

Using 6.3 percent Sales to GDP ratio for Novo Nordisk and 0.03 percent of sales to GDP ratio of "other firms" in the sample for 2022, one percent labor productivity shock to Novo Nordisk is associated with 0.06 percent of labor productivity shock to other firms next year.

Similarly, the regression coefficient for pharmaceutical industry interaction term in (2) in Table 4 suggests that one unit increase in weighted Novo labor productivity shock has 0.00962 unit increase additionally in weighted pharmaceutical industry "other firms". Using 0.08 percent of Sales to GDP ratio for pharmaceutical industry "other firms", one percent of labor productivity shock to Novo is associated with 0.75 percent additional increase in labor productivity shock to other firms in the pharmaceutical industry next year.

B. Additional Information on the Second Set of Regressions

Annex I. Table 1. Denmark: List of Firm-Level Control Variables

Control variable	Calculation
Cash flows	Cash flows from operating activities, divided by total assets
Leverage	Sum of short-term and long-term debts, divided by total assets
Loss	Dummy variable that takes the value of 1 when operating income is negative and otherwise.
Size	Natural logarithm of total assets

Annex I. Table 2. Denmark: Regression Results: Impact of Firm-Specific Shocks to the Smaller Firms

	(1) ScaledShocks(Other)$_t$	(2) ScaledShocks(Other)$_t$
ScaledShocks(Novo)$_{t-1}$	0.000339	0.000259
	(1.11)	(0.82)
ScaledShocks(Other)$_{t-1}$	-0.295***	-0.297***
	(-4.53)	(-4.59)
Cash_flow_asset$_{t-1}$	-0.349	-0.337
	(-1.04)	(-1.02)
Leverage$_{t-1}$	0.268**	0.256**
	(2.30)	(2.14)
Loss$_{t-1}$	-0.0501	-0.0462
	(-0.76)	(-0.70)
Size$_{t-1}$	-0.0720	-0.0709
	(-0.97)	(-0.95)
ScaledShocks(Novo)$_{t-1}$* Pharma_Dummy		0.00962**
		(2.30)
Constant	1.022	1.009
	(0.81)	(0.80)
N	7745	7745
R^2		

Note: t statistics in parentheses, * p<0.1, ** p<0.05, *** p<0.01.

References

Garbaix, Xavier (2011). "The Granular Origins of Aggregate Fluctuations." Econometrica 79(3), 733–772.

Jannati, Sima (2020). "Geographic Spillover of Dominant Firms' Shocks." Journal of Banking and Finance 118 1–17.

Productivity Board (2024a), "Use of Merchanting and Processing by Undertakings." Productivity 2024, Chapter 2.

Productivity Board (2024b), "The Impact of Merchanting and Processing on the Economy." Productivity 2024, Chapter 3.

Statistics Denmark (2019), "Production Abroad Has an Effect on Danish GDP."