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A SUB-SECTORAL APPROACH ON THE NEXUS BETWEEN R&D AND VALUE-ADDED IN OECD COUNTRIES

OECD ÜLKELERİNDE AR-GE VE KATMA DEĞER İLİŞKİSİNE ALT-SEKTÖREL BİR YAKLAŞIM

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ABSTRACT

This study aims to investigate the impact of R&D expenditures on added values of manufacturing sub-sectors in OECD countries. The data cover the period 1998-2015. Cointegration tests validate long-run relationship for each model. Long-run coefficient estimates show R&D elasticities of added values are 0.3 and 0.4 for 'food, beverages, and tobacco'; 0.7 and 0.8 for 'machinery and transportation equipment'; 0.5 and 0.6 for 'medium and high-tech industry'; -0.30 and -0.31 for 'textiles and clothing'; and 0.4 and 0.35 for 'chemicals'. Lastly, causality tests reveal a causality from R&D expenditures to value-added of 'food, beverages, and tobacco' sub-sector.

Keywords: R&D, Innovation, Value-added, Manufacturing, OECD

ÖZ

Bu çalışma OECD ülkelerinde Ar-Ge harcamalarının imalat sanayi alt sektörlerinin katma değerlerine etkilerini incelemeyi amaçlamaktadır. Veriler 1998-2015 dönemini kapsamaktadır. Eşbütünleşme testleri tüm modeller için uzun dönemli ilişkileri onaylamıştır. Uzun dönem katsayı tahminlerine göre Ar-Ge esneklikleri "yiyecek, içecek ve tütün" alt sektörü için 0.3 ve 0.4; "makine ve taşımacılık ekipmanları alt sektörü" için 0.7 ve 0.8; "orta ve yüksek teknoloji sanayi alt sektörü" için 0.5 ve 0.6; "tekstil ve giyim alt sektörü" için -0.30 ve -0.31; ve "kimyasallar alt sektörü" için 0.4 ve 0.35'tir. Son olarak nedensellik testleri Ar-Ge harcamalarının "yiyecek, içecek ve tütün" alt sektörünün katma değerinin Granger-nedeni olduğunu göstermiştir

Anahtar Sözcükler: Ar-Ge, Yenilik, Katma Değer, İmalat, OECD

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1. Introduction

Research and development (R&D) is undeniable in the process of transforming inputs into outputs. As described in detail in Frascati Manual (OECD, 2015: 44), R&D can be defined briefly as "systematic and creative studies aimed at increasing knowledge stock, and designing new applications with it". R&D is expected to bring innovation. Innovation dealt with various aspects in Oslo Manual (OECD/Eurostat, 2005: 46) can also be described as "the application of new or enhanced product, process, marketing or organization method". Innovation is also expected to increase output and productivity. The process from R&D to innovation and from innovation to output is investigated and popularized by Crepon, Deuget, & Mairesse (1998) and the model they suggest, which is known as CDM model, is still being extensively used in literature today (i.e. Acosta, Coronado, & Romero, 2015; and Fu, Mohnen, & Zanello, 2018).

However, it is ambiguous that innovation leads to increase in total output. Kleinknecht (2000: 169-186) explains strengths and weaknesses of R&D and patents. It can be said that the common strength of R&D and patents are that they both have large historical datasets (2000: 170 and 172). Perhaps the weakest aspect of R&D is that it is only an input (2000: 170). On the other hand, patents do not involve non-patented and non-patentable inventions. Also, there is the possibility that patents may not be turned into commercial products (2000: 172). Furthermore, Comanor & Sherer (1969) indicate that patenting propensity to the inventions with a certain quality has declined, and that patenting propensity changes across industries and firms. Considering its strengths and weaknesses, and easy access to its sub-sectoral data, R&D expenditures are preferred as an innovation indicator in this study.

There is a vast amount of papers in the literature on the nexus between R&D and output. The literature can be divided by the results, methodologies or variables for the review. However, it can easily be seen that the literature is already dichotomous as macroeconomic and microeconomic studies. In other words, a certain part of the literature examines on macro issues when the other part deals with micro issues.

Generally, macroeconomic works in the literature use GDP or economic growth as dependent variable. Among them, Choi & Yi (2018) show that increases in R&D and internet strengthen each other's positive effects on economic growth. Bozkurt (2015) reveal that increases in the share of R&D in GDP positively affect economic growth, and GDP causes the share of R&D in Turkey. Sylwester (2001) asserts positive effects of R&D on GDP in G7 countries but no significant effect in OECD countries. Finally, Falk (2007) discovers business R&D share in GDP and R&D share in high-tech sector have positive impacts on GDP. Productivity and productivity growth are other frequently used macro variables. For example, Erdil, Cilasun, & Eruygur (2013) for the panel of 22 OECD countries reveal delayed positive effects of R&D on productivity, and verify R&D expenditures increase productivity growth in the long-run. Also, Bravo-Ortega & Marin (2011) for the panel of 65 countries reveal that R&D expenditure per capita has positive effects on total factor productivity. Even the effect of R&D on output is overwhelmingly positive in macroeconomic literature, a causal look suggests various results. For instance, Peng (2010) for China, and Yang (2006) for Taiwan find that R&D causes GDP. However, Bozkurt (2015) for Turkey, and Doyar (2019) for Canada indicate that GDP causes R&D. Also the relationship can be bidirectional as in Wu, Zhou, & Li (2007) for China when there can be no relationship as in Sadraoui, Ali, & Deguachi (2014) for 32 countries.

Microeconomic part of the literature mostly employs dependent variables such as output and productivity at the firm level. In this context, Griliches (1964) finds public investment in research and extension positively affects agricultural value added in 39 US states. Hu (2001) refers positive effects of private R&D on output of Chinese industry. Tsang, Yip, & Toh (2008) state that foreign firms generate more value added than domestic firms in terms of four types of R&D in Singapore. Verspagen (1995) reveals that R&D capital per employee promotes output only in high-tech sector when it has no effect in low and mid-tech sectors for 15 manufacturing sectors in 11 OECD countries. Among the works in latter part of the microeconomic literature use productivity, Harhoff (1998) finds that the positive impact of R&D capital stock per employee on productivity for high technology firms in German manufacturing firms is higher than that of the other firms in the sample. However, a part of the literature uses diversified R&D variables. Guellec & de la Potterie (2001) emphasize that the greatest effect on multifactor productivity in 16 OECD countries is due to foreign R&D. Lastly, Lokshin, Belderbos, & Carree (2008) for Dutch manufacturing firms, and Kancs & Siliverstovs (2016) for the firms in OECD countries find non-linear relationships between R&D and productivity.

The aim of current study is to examine the effects of R&D expenditures on added values of 'food, beverages, and tobacco', 'machinery and transport equipment', 'medium and high-tech industry', 'textiles and clothing', and 'chemicals' sub-sectors in OECD countries. To the best of my knowledge, there is no paper that study R&D and output relationship for OECD countries in the sub-sectoral context with up-to-date data. Exploiting data from 1998 to 2005, unit root tests, cointegration tests, coefficient estimation techniques, and a causality test are applied. Results of cointegration tests show that the added value of each sub-sector has long-run relationship with R&D expenditures. According to the estimated long-run coefficients, when the R&D expenditures affect the added value of 'textiles and clothing' sub-sector negatively, it affects the added values of each of the other sub-sectors positively. Finally, only causality is detected in the food sub-sector, and it runs from R&D expenditures to added value.

2. Data, Model, and Methodology

2.1. Data

The data used are annual observations for 28 OECD countries[1] for the period 1998-2015 and are taken from the World Bank's (2019) World Development Indicators database. Cross section and time dimensions are determined by data availability. Therefore, 7 countries (Canada, Chile, Czech Republic, Israel, Lithuania, Luxembourg, New Zealand and Switzerland) are dropped from the panel, and the period is restricted to 1998-2015 because of insufficient number of observations.

Sub-sector data are given as percentage share in manufacturing industry. Value added series for sub-sectors are calculated using manufacturing industry value added (constant 2010 US$) series. R&D expenditures series is also given as percentage share in GDP. R&D expenditures variable is expressed in terms of money using GDP (constant 2010 US$) series.[2] The variables with their abbreviations are elaborated in Table 1.

1 Australia, Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Latvia, Mexico, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Turkey, United Kingdom, and United States.

2 If the observation A_t is missing, then it is compensated using $(A_{(t-1)}+A_{(t+1)})/2$ formula if possible.

Table 1. Variables

Variable	Abbreviation
Value added of 'food, beverages and tobacco' sub-sector (constant 2010 US$)	food
Value added of 'machinery and transport equipment' sub-sector (constant 2010 US$)	mach
Value added of 'medium and high-tech industry' sub-sector (constant 2010 US$)	tech
Value added of 'textiles and clothing' sub-sector (constant 2010 US$)	cloth
Value added of 'chemicals' sub-sector (constant 2010 US$)	chem
Research and development expenditure (constant 2010 US$)	rd

2.2. Model

In fact, there are definitely lots of variables determining the added values of these five subsectors. However, they presumably vary among the sub-sectors. It is also highly difficult to reach them. Moreover, the variables that can be reached do not share the same base year and the exchange rate for each country. Therefore, assuming Ockham's razor is very sharp for practical reasons, R&D expenditure is left as the only determinant of added values. In such a case, the model is given by:

$$\textit{Value Added} = e^{\beta_0} (R\&D)^{\beta_1} e^{u} \quad (1)$$

Taking natural logarithms of both sides considering that e is Euler's number gives:

$$\log(\text{Value Added})_{i,t}^{\lambda} = \beta_0^{\lambda} + \beta_1^{\lambda} \log(R\&D)_{i,t} + u_{i,t}^{\lambda} \quad (2)$$

Here, i and t are added to denote country and time, respectively. log indicates natural logarithm. β_0 is constant term when β_1 show the R&D elasticity of value added. u stands for error term. Finally, λ=1,2,…,5 represent sub-sectors. This character is added to avoid writing five different models.

Scatter plots of the variables are given in Appendix (see Figures A1 to A5). It can be said that each variable is in a positive relationship with log *rd*. However, the relationship between log *clothes* and log *rd* (Figure A4) seems more ambiguous than the others due to the diffusion of the observations.

2.3. Methodology

Stability of the variables is examined using Im, Pesaran, and Shin (2003) and two Fisher-type (Maddala & Wu, 1999; Choi, 2001) unit root tests. Then, cointegration between the variables is investigated by Pedroni (1999, 2004) and Kao (1999) cointegration tests. These are residual-based panel cointegration tests, and built upon Engle & Granger (1987) procedure. When Kao's (1999) test imposes homogeneity of cointegrating vectors, Pedroni's (1999, 2004) test allows heterogeneity in the errors through cross-sections (Asteriou & Hall, 2011: 449-450).

Long-run coefficients are estimated employing Pedroni's (2000, 2001) fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) methods. Using Monte Carlo simulations, Chiang & Kao (2001) compare finite sample properties of OLS, FMOLS, and DOLS estimators. When estimating cointegrating regressions, they propose the use of DOLS since the OLS and FMOLS estimators considerably biased in finite samples.

Finally, causal relationships investigated using Dumitrescu & Hurlin's (2012) panel causality test. Their procedure takes into consideration the heterogeneity of both causal relationships and the regression model (which is used to test Granger causality). In this procedure, the null hypothesis is "X does not Granger-cause Y in any of the cross-section" when the alternative hypothesis is "X Granger-causes Y at least in one cross-section".

Unit root and cointegration tests, and coefficient estimates are done using Eviews 9. Causality tests are run on Stata 14 using the command written by Lopez & Weber (2018).

3. Empirical Findings

Results of unit root tests are presented on Table 2. LLC test shows that all variables are stationary except log *chemical*. Other unit root tests mostly indicate that all the variables are stationary in the first differences. Since the variables are stationary in their first differences, cointegration is analyzed.

Table 2. Results of unit root tests

	IPS (W)		ADF-F (χ2)		PP-F (χ2)	
	Level	Difference	Level	Difference	Level	Difference
log *food*	-0.065	-18.82***	69.42	369.6***	93.27***	699.6***
log *machine*	1.759	-16.22***	52.13	320.2***	67.09	530.0***
log *tech*	-0.975	-13.64***	67.13	269.7***	75.05	666.5***
log *clothes*	1.276	-16.97***	49.32	341.4***	72.10*	873.4***
log *chemical*	0.526	-13.48***	56.59	279.3***	55.73	436.8***
log *rd*	1.364	-9.834***	51.64	203.5***	63.17	194.2***

***, **, and * show the rejection of the null of unit root at 1%, 5%, and 10% levels, respectively. Lag lengths are determined by Schwarz information criterion. Long-run variances are estimated by Bartlett kernel. Bandwidths are selected by Newey-West.

Table 3. Results of cointegration tests

	(1) Food	(2) Mach	(3) Tech	(4) Cloth	(5) Chem
Pedroni Panel *v*-statistic	0.3616	0.6429	1.0966	1.5230*	4.8244***
Pedroni Panel *rho*-statistic	-2.2484***	-0.8883	-0.7174	-3.3085***	-4.3164***
Pedroni Panel *PP*-statistic	-2.8269***	-2.2442**	-1.7259**	-5.1449***	-4.5482***
Pedroni Panel *ADF*-statistic	-5.5134***	-3.2916***	-4.0112***	-6.1167***	-5.0240***
Pedroni Group *rho*-statistic	-0.3373	-0.2708	-0.6504	-0.9252	-0.5443
Pedroni Group *PP*-statistic	-3.0182***	-4.1933***	-4.7990***	-4.3651***	-3.0414***
Pedroni Group *ADF*-statistic	-4.7357***	-4.4122**	-5.9337***	-5.3500***	-3.5983***
Kao *ADF*-statistic	-0.6158	-1.6073*	-2.9489***	2.2966**	-2.4572***

***, **, and * show the rejection of the null of no cointegration at 1%, 5%, and 10% levels, respectively. Lag lengths are determined by Schwarz information criterion. Long-run variances are estimated by Bartlett kernel. Bandwidths are selected by Newey-West.

Table 3 shows results of cointegration tests. Out of seven test statistics in Pedroni (1999, 2004) cointegration test, five for food model, four for machine model, four for tech model, six for clothes model, and six for chemical model are rejected the null of no cointegration. Also, Kao (1999) cointegration test approves these results except for food model.

Long-run coefficients are estimated by FMOLS and DOLS methods. These results are given on Table 4. In both estimates, log *rd* coefficients are statistically significant at 1% level for each model. Also, R^2 values are around 99%. Within the sub-sectors covered, R&D expenditures mostly affect the value added of machinery and transport equipment. Accordingly, 1% increase in R&D expenditures will increase the value added of machinery and transportation equipment by 0.7% to 0.8%. The second highest impact is on value added of medium and high-tech industry. 1% increase in R&D expenditures will increase the value added of medium and high-tech industry between 0.5% and 0.6%. The other two sectors which are positively affected by R&D expenditures are chemicals and food, beverage and tobacco sectors. A 1% increase in R&D expenditures will increase the value added of chemicals by 0.4% to 0.35% while by 0.3% to 0.4% for the value added of food, beverages and tobacco.

Table 4. Long-run coefficient estimates

	log *food*	log *mach*	log *tech*	log *cloth*	log *chem*
FMOLS	0.3656*** (0.0407)	0.7850*** (0.0511)	0.6484*** (0.0377)	-0.2963*** (0.0573)	0.4099*** (0.0499)
DOLS	0.2803*** (0.0427)	0.6750*** (0.0472)	0.5470*** (0.0324)	-0.3095*** (0.0560)	0.3500*** (0.0517)

***, **, and * show statistical significance at 1%, 5%, and 10% levels, respectively.

The only sub-sector that negatively affected by R&D expenditures is the textiles and clothing sub-sector. The 1% increase in R&D expenditures reduces the value added of textiles and clothing by 0.3% to 0.31%.

Table 5. Results of causality tests

Null hypotheses	k	Z-bar
Δ log *rd* does not Granger-cause Δ log *food*	1	3.6364***
Δ log *food* does not Granger-cause Δ log *rd*	1	1.3455
Δ log *rd* does not Granger-cause Δ log *machine*	1	1.2303
Δ log *machine* does not Granger-cause Δ log *rd*	1	1.4228
Δ log *rd* does not Granger-cause Δ log *tech*	1	-0.7344
Δ log *tech* does not Granger-cause Δ log *rd*	1	0.7921
Δ log *rd* does not Granger-cause Δ log *clothes*	1	1.0594
Δ log *clothes* does not Granger-cause Δ log *rd*	1	1.0766
Δ log *rd* does not Granger-cause Δ log *chemical*	1	0.0065
Δ log *chemical* does not Granger-cause Δ log *rd*	1	0.1618

*** shows the rejection of null of no causality at 1% level. Δ is difference operator. Optimal lag length (k) is determined by Akaike information criterion since Schwarz information criterion is not an option in the command of Lopez and Weber (2018).

Table 5 presents results of causality tests. As it is understood, the null hypothesis of "Δ log *rd* does not Granger-cause Δ log *food*" is rejected at 1% level of significance. This means that R&D expenditures Granger-cause value added of food, beverage, and tobacco sub-sector. However, all of other null hypotheses cannot be rejected. Therefore, it is concluded that there is no causal relationship between value added of other sub-sectors and R&D expenditures.

4. Conclusions

This paper aims to reveal the nexus between value added of manufacturing sub-sectors and R&D expenditures in OECD countries. For this purpose, data from 1998 to 2015 on R&D expenditures and added values of manufacturing sub-sectors, namely (i) food, beverages, and tobacco, (ii) machinery and transport equipment, (iii) medium and high-tech industry, (iv) textiles and clothing, and (v) chemicals. Pedroni (1999, 2004) and Kao (1999) cointegration tests show that each value added is cointegrated with R&D expenditures. Then the magnitudes of the relationships are estimated. FMOLS and DOLS estimates indicate that R&D expenditures positively affect added values, except for value added of textiles and clothing. At the final step, causal relationships between added values and R&D expenditures are examined using Dumitrescu & Hurlin's (2012) procedure. Results show that there is a unidirectional causality from R&D expenditures to value added of food, beverages, and tobacco subsector at least in one country. However, no causal relationship is detected in any way between other added values and R&D expenditures.

The results on coefficient estimates except for textiles and clothing are in parallel with most of the studies discussed in the literature which suggests positive effects of R&D on added value. However, R&D expenditures have negative effects on added value of textiles and clothing sub-sector. This result may be due to the labor-intensive nature of the textiles and clothing sector. All these findings indicate the importance of R&D expenditures in manufacturing sub-sectors in OECD countries except textiles and clothing. This implication is also supported especially for food, beverages, and tobacco sub-sector when the causality result is taken into consideration.

Data Availability Statement

Publicly available datasets were analyzed in this study. The data used are annual observations for 28 OECD countries for the period 1998-2015 and are taken from the World Bank's (2019) World Development Indicators database.

Ethics Statement

No human studies are presented in this manuscript.

Author Contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of Interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendices

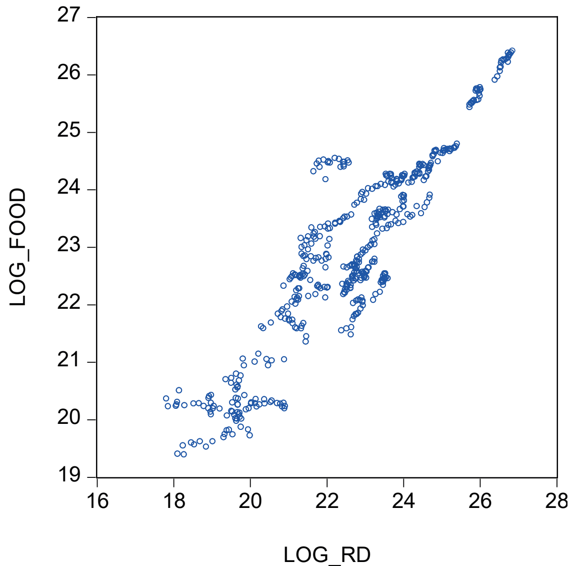

Figure A1. Scatter plot of log *rd* on log *food*

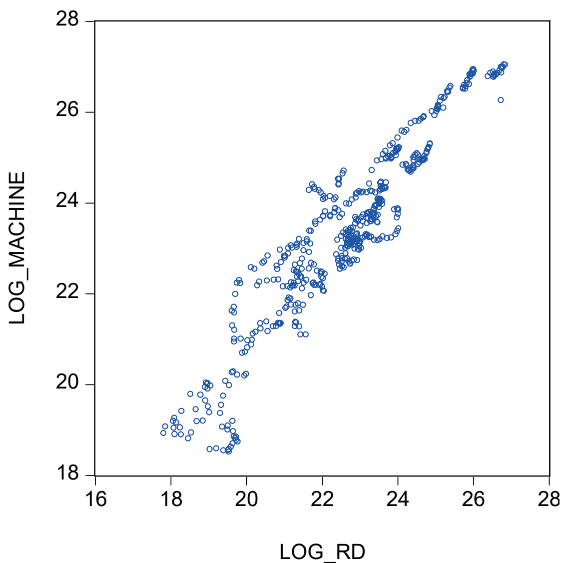

Figure A2. Scatter plot of log *rd* on log *mach*

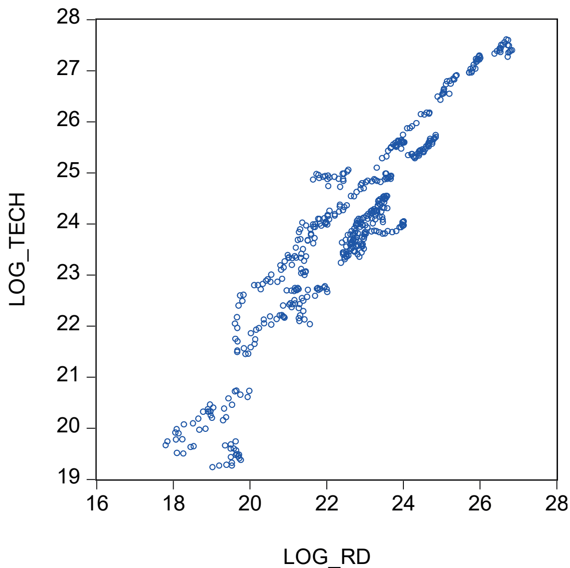

Figure A3. Scatter plot of log *rd* on log *tech*

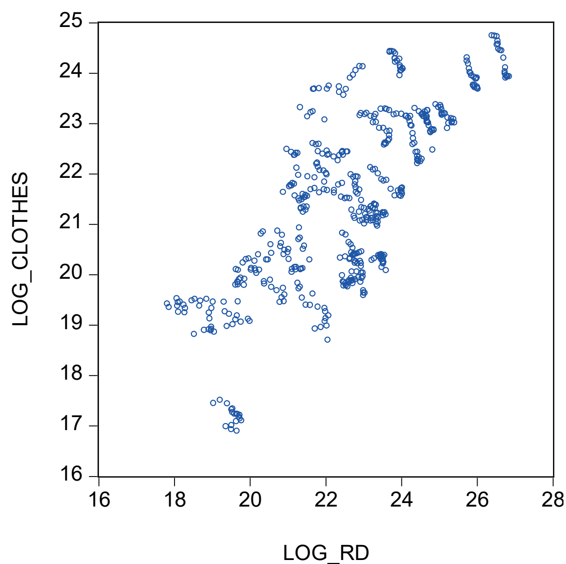

Figure A4. Scatter plot of log *rd* on log *cloth*

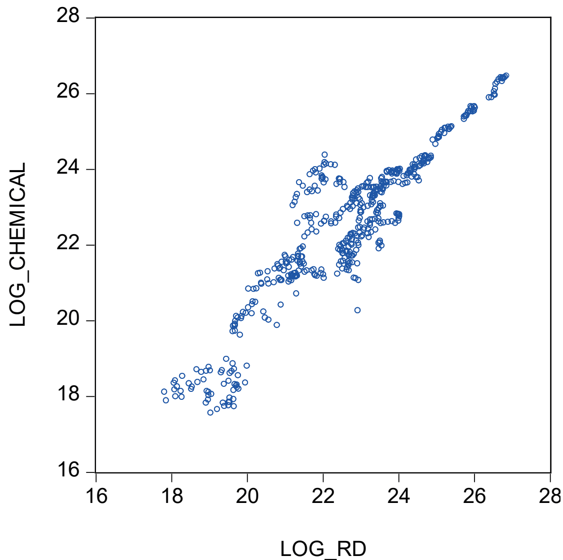

Figure A5. Scatter plot of log *rd* on log *chem*