DO BUSINESS CYCLES INFLUENCE LONG-RUN GROWTH? THE EFFECT OF AGGREGATE DEMAND ON FIRM-FINANCED R&D EXPENDITURES

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Do business cycles influence long-run growth? Traditional macroeconomics says no and treats business cycles and growth as separate phenomena. If business cycles influence productivity, however, they might influence long-run growth. This paper examines one potential link between business cycles and growth: firm-financed R&D expenditures.

Many economists believe business cycles should negatively affect growth. Ramey and Ramey [1995] use output volatility as a measure of the business cycle and find that increased volatility reduces growth. Geroski and Walters [1995] find a positive relationship between inventive activity and demand in the United Kingdom. If negative demand shocks make output more volatile, the Geroski and Walters [1995] finding might explain why volatility reduces growth.

One might not think that volatility should matter for long-run growth since the decrease in inventive activity during recessions is offset by the increased inventive activity during expansions. The business cycle, however, is asymmetric with longer and less steep expansions than recessions. This means that the effect of recessions may exceed the effect of expansions or vice versa. Even if the business cycle were symmetrical, increased volatility may reduce firm-financed R&D in much the same way that increased volatility reduces investment if there are irreversibilities associated with R&D projects. This argument is similar to the argument developed by Bernanke [1983] and Pindyck [1991].

A number of factors may explain why inventive activity increases with demand. In this paper, I focus on the ability of firms to finance inventive activities out of cash flow (the cash-flow effect). For example, during expansions credit constraints slacken and firms increase investment and inventive activity, but during recessions the constraints bind and firms decrease these activities. Hall [1992], Himmelberg and Petersen [1994], and Mulkay, Hall, and Mairesse [2001] find a significant amount of evidence supporting the view that firm-financed R&D expenditures respond to cash flow. Asymmetries in the business cycles suggest that the business cycle might have a net positive or net negative effect on R&D expenditures. In this case, recessions and expansions can have long-run effects by changing the amount of R&D expenditures.

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The claim that inventive activity is procyclical is controversial. Bean [1990], Hall [1991], and Saint-Paul [1993] argue that inventive activity should be countercyclical. Bean [1990] finds that human capital accumulation is countercyclical, Hall [1991] argue that "organizational capital" accumulates more quickly during recessions and Saint-Paul [1993] finds evidence that negative aggregate demand shocks stimulate productivity growth. The countercyclical behavior is explained by the existence of an opportunity-cost effect: the return to inventive activity is stable over the business cycle, but the return to producing output is temporarily high during expansions and temporarily low during recessions, causing the relative return to inventive activity to fall during expansions and rise during recessions. Consequently, recessions may improve the long-run health of economies by stimulating inventive activity and the aggregate supply side of the economy. Once again, if the business cycle is asymmetric then the business cycle can have long-run effects by causing a net increase or net decrease in inventive activity.

Determining whether inventive activity is procyclical or countercyclical is important, but does not necessarily tell us whether the business cycle stimulates or retards inventive activity. Blackburn [1999] argues that if inventive activity is procyclical, the "extra" inventive activity from expansions may exceed the "lost" R&D from recessions. This would mean that the business cycle as a whole would stimulate inventive activity.

In this paper, I test the opportunity-cost and cash-flow effects against each other by examining the short-run and long-run relationships between R&D and demand. The data suggest that increased cash flow leads to increased R&D, which implies that R&D is procyclical. The result is also asymmetric with more R&D lost during recessions than gained during expansions so business cycles as a whole reduce R&D. The results are not consistent with the opportunity-cost hypothesis and suggest that business cycles might reduce long-run growth. The results also suggest that policy makers might want to fill in the valleys of the business cycle to prevent losing firm R&D, but let expansions proceed unchecked to maximize firm-financed R&D expenditures.

DATA DESCRIPTION AND RESULTS

Data

This paper differs from most of the previous work on the opportunity-cost effect because it uses firm-financed R&D expenditures as the measure of inventive activity.[1] A measure of inventive inputs, like firm-financed R&D, is appropriate because the opportunity-cost and cash-flow effects are hypotheses about what determines the level of resources devoted to inventive activity. Bean [1990], Saint-Paul [1993] and Gali and Hammour [1992] use total factor productivity (TFP) as a measure of inventive activity, but this is at best a measure of inventive output. Saint-Paul [1993] consider firm R&D expenditures as an alternative measure of inventive activity, but finds no relationship between aggregate demand shocks and R&D expenditures for countries in the Organization for Economic Co-operation and Development. This paper focuses on the United States, which has collected data on firm-financed R&D expenditures for a longer time period than other countries.

The nature of the R&D data used in this paper creates a bias against finding a relationship between R&D and aggregate demand. R&D data is available on a yearly basis from the National Science Foundation since 1953. From 1953 to 1991, the National Science Foundation had the United States Bureau of the Census draw a sample of firms every five or six years and sent these firms surveys concerning R&D activities. In the intervening years only the firms reporting more than $1 million of R&D were surveyed. These surveys, therefore, systematically missed new entrants and R&D conducted by small firms. Since small and new entrants are likely those most subject to cash-flow constraints, the official R&D statistics might understate how responsive R&D expenditures are to demand. Fortunately, the National Science Foundation updated its R&D estimates when it drew a new sample, which helped to mitigate the problem. In 1992, the National Science Foundation started drawing a new sample of firms each year, which should reduce the problem even further. The design of the surveys created a bias against finding a relationship between R&D and demand. In addition, this paper uses aggregate data, which should make it harder to find a clear cyclical pattern in R&D expenditures since many industries have different cyclical behavior. Even with these two biases against finding a cyclical pattern in R&D, however, a cyclical pattern does emerge.

Using aggregate data also has one advantage. Policymakers possess blunt tools that let them influence the national business cycle, but are unable to influence the cycles in individual industries. From a practical point of view, policymakers can do something about cyclical R&D expenditures only if that cyclical pattern emerges at the national level. Cyclical R&D and inventive activity, therefore, is a practical concern only if the cycle emerges on a national level.

The other variables used in this paper are: government-financed R&D expenditures, cash flow, and GDP. All variables are annual data from 1953 to 1999 and the variables are in natural logarithms of constant 1996 dollars. Government R&D expenditures control for any "crowding-in" or "crowding-out" that government R&D might have on firm R&D. After-tax cash flow is a measure of resources available for R&D.[2] Hall [1992] finds strong statistical evidence suggesting that U.S. firms finance most R&D expenditures through their own resources. In addition, Himmelberg and Petersen [1994] and Mulkay, Hall and Mairesse [2001] find evidence that firm-financed R&D expenditures respond to cash flow. GDP is used as a measure of the demand for goods and services. When GDP is high, the return to producing output is temporarily high since goods might sell for a higher price and not sit in inventories for an extended period. Conversely, when GDP is low the return to producing output is temporarily low since goods might sell for a lower price and sit in inventories for an extended period.[3]

Results

All of the variables in this study exhibit a persistent upwards trend, which suggests that each variable may contain a unit root. Indeed, Phillips-Perron and augmented Dickey-Fuller unit root tests fail to reject the null-hypothesis of a unit root for all the variables.[4] This raises the possibility that one or more of the variables are cointegrated. In addition, the opportunity-cost effect suggests that the long-run and short-run effects of a change in demand on inventive activity may differ. Initially, a positive demand shock may decrease inventive activity as firms divert resources to take advantage of the temporarily high price of goods, but over time the forces stressed by the standard neoclassical view of investment begin to dominate and inventive activity expands as the size of the market increases.

To derive the model used in this paper, one can start with an autoregressive distributed lag of the form:

$$RD_t = \mu + \sum_{k=1}^{l} \theta_k RD_{t-k} + \sum_{n=0}^{l} \rho_n GDP_{t-n} + \varepsilon_t \tag{1}$$

where RD_t is the level of firm-financed R&D expenditures, GDP_t is the level of GDP and ε_t is an error term of mean zero and constant variance. Hendry, Pagan and Sargan [1984] show that equation (1) may be written as:

$$\Delta RD_t = \alpha + \sum_{i=1}^{l-1} \beta_i \Delta RD_{t-i} + \sum_{j=0}^{l-1} \gamma_j \Delta GDP_{t-j} + \delta\left(RD_{t-1} - \lambda GDP_{t-1}\right) + \varepsilon_t , \tag{2}$$

where Δ represents the first difference, λ is the cointegrating relationship between firm R&D and GDP and δ, is the speed of adjustment term. One can augment equation (2) with additional variables that may influence the dynamics of firm-financed R&D expenditures. Mulkay, Hall and Mairesse [2001] augment an equation similar to equation (2) with a cash flow variable to study the effect of cash flow on firm-financed R&D. Following their approach, this paper augments equation (2) with the growth rate of cash flow to account for financial constraints and the growth rate of government R&D expenditures to account for any crowding-in or crowding-out effects. This paper, therefore, uses an error-correction model of the form:

$$\begin{aligned} \Delta RD_t = {} & \alpha + \sum_{i=1}^{l-1} \beta_i \Delta RD_{t-i} + \sum_{j=0}^{l-1} \eta_j \Delta Govt_{t-j} + \sum_{j=0}^{l-1} \varphi_j \Delta CF_{t-j} + \sum_{j=0}^{l-1} \gamma_j \Delta GDP_{t-j} \\ & + \delta\left(RD_{t-1} - \lambda GDP_{t-1}\right) + \varepsilon_t \end{aligned} \tag{3}$$

where $Govt_t$ is government financed R&D and CF_t is cash flow. If the opportunity-cost effect exists then one would expect γ_js < 0 and if the cash-flow effect exists then one would expect that φ_js >0. The sign on the η_js will determine whether government-financed R&D expenditures crowd in or crowd out firm-financed R&D.

Long-Run. Since λ is unknown, one cannot estimate equation (3) using ordinary least squares. Numerous non-linear and two-step methods exist, however, that allow one to estimate equation (3). Geroski and Walters [1995] use the Engle-Granger

TABLE 1
Cointegrating Relationship

Estimation Period: 1957 – 1999
Dependent Variable: Firm-Financed R&D
Estimation Method: Johansen's method

Variable	Coefficient
GDP	1.377 (0.066)
Dummy post-1981	0.161 (0.048)
Dummy post-1991	0.073 (0.035)

Coefficient estimates appear first with standard errors in parentheses.

two-step method to estimate a model similar to equation (3). The disadvantage of the Engle-Granger two-step procedure is that initial regression in the levels of the variables might provide misleading estimates of λ if the R^2 for the first stage regression is low. Low R^2 for the initial regression in levels might occur if the cash-flow and opportunity-cost effects explain a large percentage of the growth rate of firm-financed R&D expenditures.

This paper also uses a two-step procedure. The first step is to use the Johansen method developed by Johansen [1991;1995] and Johansen and Juselius [1990] to estimate a cointegrating relationship between firm-financed R&D and GDP. Given this estimate of λ, an error-correction model is estimated in the second step. The advantage of this procedure is that Johansen's method simultaneously estimates the short-run and cointegrating relationships. This provides a more accurate estimate of λ, which allows for a more accurate estimate of the φ_js and the γ_js which are the coefficients of interest.

Table 1 shows the estimated cointegrating relationship of the form,

$$\text{(4)} \qquad \mathrm{RD}_t = \lambda_1 * \mathrm{GDP}_t + \lambda_2 * Dummy1981_t + \lambda_3 * Dummy1991_t \,.$$[5]

The dummy variable for the post-1981 period is included to correct for the introduction of R&D tax credit and the dummy variable for the post-1991 period is included for the change in data collection techniques. Restricting these two dummy variables to the cointegrating relationship is the same as assuming that the two changes cause a one-time shift in the intercept of the cointegrating relationship. The data suggest that a 1 percent increase in real GDP increases R&D expenditures by 1.377 percent in the long run.[6] This is consistent with studies such as Mulkay, Hall and Mairesse [2001], which examine the long-run relationship between R&D and sales at the firm level. This result is also consistent with the persistent upwards trend of firm-financed R&D expenditures as a share of GDP. The coefficients on the dummy variables are consistent with the views that the R&D tax credit stimulate firm-financed R&D and that the pre-1991 R&D surveys underreport actual firm-financed R&D expenditures.

Short-Run. Given the estimates of the cointegrating relationship, one can estimate equation (3) to obtain estimates of the cash-flow and opportunity-cost effects. However, there is the possibility of simultaneity bias if one uses ordinary least squares to estimate equation (3). The current growth rate of firm-financed R&D expenditures, for example, might influence the current growth rate of government financed R&D, which would cause a simultaneity bias. In addition, all four variables may experience common shocks, which suggest an efficiency gain of using seemingly unrelated regression techniques.

To account for these two issues, this paper estimates a system of error-correction models using three-stage least squares. The system contains one equation for each of the four variables in the model and the equation for each variable contains the error-correction term. Statistically insignificant variables are then excluded from the system. Table 2 contains the estimates for the parsimonious system.[7] The χ^2-statistic for the test of the over-identifying restrictions is 47.094, the test has 38 degrees of freedom, and the p-value for the test is 0.130.

The most interesting aspect of the short-run model is the influence of the growth rate of cash flow on the growth rate of firm R&D. The coefficient implies that when cash flow grows by 1 percent, R&D increases by 0.254 percent during the same year. This is exactly what one would expect from the cash-flow effect; rising cash flow allows credit-rationed firms to increase R&D activities. This is consistent with Himmelberg and Petersen [1994], Mulkay, Hall and Mairesse [2001], and most firm-level studies of the relationship between investment expenditures and cash flow. The effect is statistically significant at the 95 percent level and may actually underestimate the responsiveness of firm-financed R&D to cash flow. First, the data collection method of the National Science Foundation used for most of the sample period will systematically miss small firms and new entrants, which are the firms most likely to experience severe cash-flow constraints. Second, the data is aggregate, and aggregate data tends to average out the differing cyclical behaviors of different industries and individual firms. Even with these two biases against finding a response of R&D to cash flow, the data suggest that aggregate firm-financed R&D expenditures do respond to cash flow.

The short-run model also shows no sign of the opportunity-cost effect since the data do not reject imposing the restriction that the current and lagged growth rates of GDP have zero coefficients. The absence of evidence for the opportunity-cost effect is not surprising when one considers the high adjustment costs for R&D projects. After all, it is hard to believe that firms move the same workers from research to production line activities or stop building factories to devote more resources to R&D depending upon the state of the business cycle. Bernstein and Nadiri [1988] study the issue of adjustment costs and find that the adjustment costs for R&D are higher than for physical capital. In addition, Levin et al [1987] report that many firms use

TABLE 2
Parsimonious System

	Equations			
	Firm−Financed R&D Growth	**Government R&D Growth**	**GDP Growth**	**Cash Flow Growth**
Constant	−2.170 (0.634) [0.002]	−0.013 (0.007) [0.088]	0.834 (0.332) [0.016]	0.013 (0.022) [0.561]
Cash Flow Growth	0.254 (0.099) [0.014]		0.336 (0.054) [0.000]	
Cash Flow Growth (−1)			0.073 (0.031) [0.023]	
Cash Flow Growth (−2)			0.058 (0.028) [0.047]	
GDP Growth				1.658 (0.441) [0.001]
Firm-Financed R&D Growth (−1)	0.578 (0.119) [0.000]			−0.321 (0.153) [0.043]
Firm-Financed R&D Growth (−2)				−0.218 (0.140) [0.129]
Firm-Financed R&D Growth (−3)		0.331 (0.103) [0.003]	0.072 (0.047) [0.136]	
Government R&D Growth (−1)	0.156 (0.062) [0.017]	0.578 (0.084) [0.000]		
Error-Correction Term (−1)	−0.281 (0.082) [0.001]		0.106 (0.043) [0.018]	

Coefficient estimates appear first, standard errors are in parentheses and p−values are in brackets. The test of the over-identifying assumptions produces a test statistic which is $\chi^2 = 47.904$ with a p−value of 0.130.

the strategy of hiring of a competitor's research personnel as means of appropriating knowledge. These factors suggest firms would like to smooth total R&D expenditures so they are not constantly firing research personnel and creating opportunities for their competitors to acquire research knowledge. The data suggest that the margin for substituting between R&D activities and production is small.

The coefficient on the growth rate of government R&D lagged one period is positive and statistically significant at the 95 percent level. This is consistent with the view that government R&D crowds in private R&D expenditures by opening up new research possibilities, which private firms then exploit. In addition, the lagged growth rate of firm-financed R&D is positively correlated with the growth rate of government R&D, which is consistent with the view that private R&D leads to increased government R&D. These results suggest that, at the aggregate level, the complementarities between public and private R&D are more important than the substitution possibilities.

The results in this paper are consistent with the view that changes in the demand side of the economy influence firm-financed R&D. Saint-Paul [1993], however, finds that changes in demand have no effect on firm-financed R&D expenditures. The different results arise for several reasons. First, this paper focuses on the United States and, therefore, examines a longer time-span of data than the Saint-Paul [1993] study. Saint-Paul [1993] has about twenty years of R&D while this paper has over twice that amount. Second, this paper directly estimates the long-run relationships in the data rather than trying to infer these relationships using impulse response functions. Third, this paper controls for the effect of government R&D and the long-run relationship between R&D and GDP. These differences suggest that the current paper is likely to have a better estimate of the effect of demand forces on R&D expenditures.

THE BUSINESS CYCLE AND R&D

These short-run results imply that a decrease in cash flow reduces R&D expenditures, which suggests that R&D is procyclical. As Blackburn [1999] pointed out, however, just because inventive activity is procyclical does not necessarily mean that the business cycle reduces inventive activity. If the depth and length of recessions are short relative to expansions, the business cycle may actually stimulate inventive activity. In other words, recessions may reduce inventive activity expenditures. But if the ensuing expansion stimulates enough inventive activity, the net effect of the business cycle might be to increase inventive activity. If this were so, policymakers would not want to simply smooth out the business cycles since this would reduce inventive activity and might decrease productivity growth. Instead, policymakers might want to fight recessions, but let expansions proceed unchecked.

To determine the effect of the business cycle on firm-financed R&D, I calculate what the level of R&D expenditures would have been if cash flow were to grow at the trend rate in the current year where trend is defined by a linear time trend with a break in 1973. One can think of a situation where the government had used a combination of monetary and fiscal policy to smooth out the cycle in cash flow during the current year. This exercise is the equivalent of a static forecast of R&D growth assuming cash flow grows at its trend rate and all other factors remain constant. The calculation reveals the immediate effect of a change in cash flow on firm-financed R&D expenditures and ignores "feedback" effects that might occur as changes in R&D today influence future cash flow and future R&D. The static forecast of the growth rate of firm-financed R&D (ΔRD_t^F) is then used to calculate the implied forecast of firm R&D expenditures (ΔRD_t^F),

$$RD_t^F = (1 + \Delta RD_t^F)\Delta RD_{t-1}. \tag{5}$$

Cyclical R&D ($\Delta RD_t^{cyclical}$) is then just defined as

$$RD_t^{cyclical} = (RD_t - RD_t^F). \tag{6}$$

Defined this way, cyclical R&D is positive when cash flow grows faster than trend and negative when cash flow grows slower than trend.

Table 3 shows the amount of cyclical R&D expenditures during each expansion and recession from 1957 to 1999. As one would expect, every recession except one has caused R&D expenditures to decline while every expansion has caused R&D expenditures to rise. For example, the 1980/82 recession caused firms to reduce R&D expenditures by \$2.9 billion while the ensuing expansion caused expenditures to rise by \$0.164 billion. This pattern is repeated for three of the six business cycles covered by this study and only clearly reversed for two business cycles: the 1960s and 1990s. What distinguishes these two cycles is the long length of the expansion that allows for more years of faster-than-trend cash flow growth. This suggests that business cycles of typical length reduce R&D expenditures and might reduce productivity growth and long-run growth. The results are small, but are consistent with the view that demand shocks influence the aggregate supply side of the economy. Moreover, due to the nature of R&D data collection, the results probably underestimate the effect.

CONCLUSION

Even with the inherent biases in the data against finding a cyclical pattern in aggregate level, firm-financed R&D expenditures, a clear cyclical pattern emerges. Firm R&D expenditures are procyclical due to cash-flow effects, which is consistent with much of the microeconomic literature on firm R&D. The results imply that recessions might reduce long-run growth by decreasing an important inventive input: firm-financed R&D expenditures. This is true for business cycles as a whole since the "lost" R&D during recessions is greater than the "extra" R&D during expansions. At the very least, this result has important implications for stabilization policy: the optimal stabilization policy might not be to smooth out the entire business cycle, but rather to fill in the valleys of the business cycle while not shaving off the peaks. This would maximize firm R&D expenditures and increase productivity, and should increase long-run growth.

TABLE 3
Cyclical R&D

Period	Cyclical R&D	Percent of Total R&D
1957–58 **R**	−0.571	−1.702
1959	0.483	2.601
1960–61 **R**	−0.551	−1.325
1962–68	0.571	0.292
1969–70 **R**	−1.540	−2.131
1971–72	0.866	1.198
1973–75 **R**	0.140	0.117
1976–79	1.963	1.078
1980–82 **R**	−2.900	−1.674
1983–89	0.164	0.030
1990–91 **R**	−1.072	−0.538
1992–99	4.032	0.411

A positive number indicates that business cycle conditions increase R&D and a negative number indicates that business cycle conditions decrease R&D. The second column is in billions of 1996 dollars and the third column is cyclical R&D as a percentage of total R&D during a period. **R** indicates a recession based upon National Bureau of Economic Research dating periods.

While the results are interesting, they should be interpreted with caution. This paper has examined the effect of demand forces on an inventive input. It remains to be determined if these changes in cyclical R&D expenditures significantly affect productivity and long-run growth. Other channels such as learning by doing, however, might link business cycles to growth and the combined effect might be quite large. One of the primary reasons to examine R&D expenditures is that R&D expenditures are more easily measured than learning by doing and other types of inventive activity. The results in this paper suggest that macroeconomists should further examine the channels linking business cycles and long-run growth.

APPENDIX A

Firm-financed R&D: Column 38 of Table D in the National Science Foundation's National Patterns of R&D Resources 2000. Includes expenditures by firms on R&D regardless of where the research occurred. Converted to billions of 1996 dollars using GDP deflator. Paper uses natural logarithm of real expenditures.

Government-financed R&D: Column 37 of Table D in the National Science Foundations National Patterns of R&D Resources 2000. Includes expenditures by the Federal government regardless of where the research occurred. Converted to billions of 1996 dollars using GDP deflator. Paper uses natural logarithm of real expenditures.

GDP: Source: Bureau of Economic Analysis. Billions of dollars. Converted to 1996 dollars using GDP deflator. Paper uses natural logarithm of real expenditures.

Cash Flow: Source: Bureau of Economic Analysis. Billions of dollars. Converted to 1996 dollars using GDP deflator. Paper uses natural logarithm of real expenditures.

GDP Deflator: Source: Bureau of Economic Analysis. 1996 = 100.

NOTES

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1. Firm-financed R&D is all R&D funded by firms regardless of what entity performs the actual research.
2. I follow standard practice by adding R&D expenditures back to cash flow. See Himmelberg and Petersen [1994].
3. I used industrial production and final sales as alternative measures of the business cycle, but none of the results in the paper changed significantly. These results are available upon request.
4. Phillips-Perron and Augmented Dickey-Fuller versions of unit root tests fail to reject the hypothesis of a unit root for all variables. The firm-financed and government-financed R&D test equations used a post-1981 dummy variable for the introduction of the R&D tax credit and a post-1991 dummy variable to account for a change in National Science Foundation data collection techniques. The real GDP and cash-flow equations allowed for a trend break in 1973.
5. Both the trace statistic and maximum eigenvalue statistic versions of the Johansen test for cointegrating relationships suggest a single cointegrating vector. The time period for the test was 1956-1999. Akaike Information Criterion and Schwarz Information Criterion indicated a lag length of three for the test vector autoregression, but serial correlation remained in the R&D equation so a lag length of four was used since the Johansen procedure is sensitive to non-white noise residuals. Recursive residuals and Chow tests do not indicate any structural instability during the sample period the paper. Diagnostic statistics for each equation in the test vector autoregression show no sign of non-normality, serial correlation, ARCH or heteroskedasticity in the residuals. All test results are available upon request.
6. If one were to use the standard Engle-Granger two-step procedure, the estimates would be 1.322, 0.174 and 0.080 with an R^2 of 0.99 which are nearly identical to the estimates obtained from the Johansen procedure.
7. The results in the paper were robust to a number of specifications including: no cointegrating relationship, using industrial production to measure demand, using final sales to measure demand and imposing restrictions to just the firm-financed R&D equation.

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