Journal Pre-proof

The impact of economic policy uncertainty and monetary policy on R&D investment: An option pricing approach

Luis P. de la Horra, Javier Perote, Gabriel de la Fuente

PII: S0165-1765(22)00078-7
DOI: https://doi.org/10.1016/j.econlet.2022.110413
Reference: ECOLET 110413

To appear in: *Economics Letters*

Received date : 13 April 2021
Revised date : 23 February 2022
Accepted date : 25 February 2022

The impact of economic policy uncertainty and monetary policy on R&D investment: an option pricing approach

Luis P. de la Horra[1], Javier Perote[2], Gabriel de la Fuente[3]

Abstract

This paper adopts a real options approach to investigate the effects of economic policy uncertainty (EPU) and monetary policy on R&D investment. Using a panel of U.S. firms over the period 2000-2019, we show that higher (lower) EPU and contractionary (expansionary) monetary policy exert a positive (negative) and significant influence on R&D investment. Our findings shed light on the counter-intuitive behavior of R&D investments, which may help policymakers to anticipate such collateral effects.

Keywords: R&D, monetary policy, economic policy uncertainty, real options, panel data.

JEL Codes: C23, D81, E22, E52, O30.

[1] Corresponding author. Business & Economics School. Department of Financial Economics and Accounting. University of Valladolid. Address: Avda. Valle Esgueva, 6. 47011, Valladolid (Spain). Email: luispablo.horra@uva.es.

[2] School of Economics & Business. Department of Economics and Economic History. University of Salamanca. Address: Campus Miguel de Unamuno (Edif. FES) 37007 Salamanca (Spain). Email: perote@usal.es.

[3] Business & Economics School. Department of Financial Economics and Accounting. University of Valladolid. Address: Avda. Valle Esgueva, 6. 47011, Valladolid (Spain). Email: gabriel.fuente@uva.es.

The impact of economic policy uncertainty and monetary policy on R&D investment: an option pricing approach

Abstract

This paper adopts a real options approach to investigate the effects of economic policy uncertainty (EPU) and monetary policy on R&D investment. Using a panel of U.S. firms over the period 2000-2019, we show that higher (lower) EPU and contractionary (expansionary) monetary policy exert a positive (negative) and significant influence on R&D investment. Our findings shed light on the counter-intuitive behavior of R&D investments, which may help policymakers to anticipate such collateral effects.

Keywords: R&D, monetary policy, economic policy uncertainty, real options, panel data.

JEL Codes: C23, D81, E22, E52, O30.

1. Introduction

The relationship between investment, uncertainty, and monetary policy has been the subject of research by economists for decades. The existing literature suggests that economic policy uncertainty (hereinafter, EPU) discourages capital investment by increasing the value of the option to invest in the future (Baker et al., 2016; Gulen and Ion, 2016; Suh and Yang, 2021). Similarly, contractionary monetary policy based on fine-tuning the policy rate tends to have a depressing effect on capital investment (Bernanke and Blinder, 1992; Boivin et al., 2010). Some recent papers have also examined the joint effect of monetary policy and EPU on capital investment (Aastveit et al., 2017; de la Horra et al., 2021).

Interestingly, R&D investment may react differently to EPU and monetary policy. Figure 1 provides preliminary evidence on the link between these three variables.[1] Specifically, Figure 1a displays the evolution of the EPU index and business R&D investment in the U.S. as a percentage of GDP between 2000 and 2019. Contrary to what might be expected, both variables seem to move in the same direction. In Figure 1b, we plot the fed funds rate against business R&D investment to GDP. The correlation is close to zero for the whole period, but highly positive from 2009 onwards.

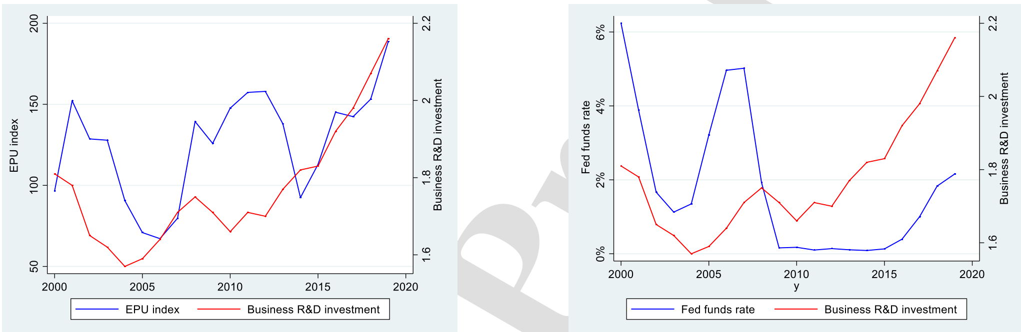

Fig. 1. Figure 1 plots the evolution of business R&D investment as a percentage of GDP against the EPU index (left graph; Fig. 1a) and the fed funds rate (right graph; Fig. 1b).

In this paper, we analyze the relationship between R&D investment, EPU, and monetary policy through the lens of the real options approach. An investment in an R&D project results in the acquisition of new knowledge or a new technology that provides the investing firm with the option (but not the obligation) to undertake a new investment in the future (i.e., a growth option; Dixit and Pindyck, 1995). Given the growth option nature of R&D projects (Kester, 1984; Mitchell and Hamilton, 1988), an increase (decrease) in uncertainty or in interest rates may enhance (reduce) their value, thereby encouraging

[1] Business R&D data have been retrieved from the National Center for Science and Engineering Statistics. The EPU index can be found at www.policyuncertainty.com. Finally, the fed funds rate has been obtained from the Federal Reserve Bank of St. Louis's database.

(discouraging) firms to invest in R&D. Using a panel of U.S. public firms over the period 2000-2019, we find that higher (lower) EPU and contractionary (expansionary) monetary policy exert a positive (negative) and significant effect on R&D investment. Furthermore, the interaction of EPU with the monetary-policy rate has a negative influence on investment in R&D projects.

This paper builds upon two different strands of the literature. First, our research relates to the literature that examines the effects of monetary policy on real variables, and more specifically on R&D investment (Moran and Queralto, 2018; Yan, 2018; Zhang et al., 2020). Second, we draw upon the part of the real options literature that analyzes the relationship between uncertainty and R&D growth options (Cho and Lee, 2020; Czarnitzki and Toole, 2013, 2011; Vo and Le, 2017; Kraft et al. 2018). We contribute to both strands in several ways. First, we provide a sound rationale for the counter-intuitive effects of EPU and monetary policy on R&D projects. Second, we extend previous research on real options by examining the impact on R&D investment of a type of exogenous uncertainty, namely EPU. The literature on growth options has primarily focused on the effects of endogenous (i.e., firm-specific) uncertainty, neglecting the influence on R&D investments of uncertainty resulting from the macroeconomic environment.[2] Finally, we shed light on the role played by the interaction between EPU and monetary policy in shaping R&D investment.

2. Hypotheses development

According to the real options approach, an investment in R&D is similar to the acquisition of a call option (Mitchell and Hamilton, 1988). When an investor purchases a call option,

[2] Recent studies suggest that macroeconomic factors may play a role in shaping R&D investment. For instance, Moran and Queralto (2018) show that expansionary monetary-policy shocks have a positive impact on R&D investment.

they acquire the right (but not the obligation) to buy the underlying financial asset at a future date. Similarly, a firm that undertakes an R&D project acquires the opportunity (but not the obligation) to undertake the underlying capital investment in the future.

Two corollaries can be derived from this analogy. First, the factors affecting the value of an R&D investment will be analogous to those affecting the value of a financial call option. Second, we can draw upon the Black-Scholes-Merton (BSM) model (Black and Scholes, 1973; Merton, 1973) for European call options to analyze the equilibrium value of an R&D project (C_0):

$$C_0 = S_0 \cdot e^{-qT} N(d_1) - X \cdot e^{-rT} N(d_2) \quad (1)$$

where S_0 is the present value of the underlying asset (i.e., the net present value of all future cash flows which the potential capital investment is expected to generate); X is the strike price (i.e., the outlay required by the underlying capital investment); T is the option's life (i.e., the period during which the underlying opportunity remains available); r is the risk-free interest rate (i.e., the monetary-policy rate); q and σ are, respectively, the cash-flow yield and the volatility of the underlying asset; $N(\cdot)$ is the cumulative normal distribution, and, finally, $d_1 = \frac{\ln\left(\frac{S_0}{X}\right) + \left(r - q + \frac{\sigma^2}{2}\right) \cdot T}{\sigma \cdot \sqrt{T}}$, and $d_2 = d_1 - \sigma \cdot \sqrt{T}$.

By differentiating Eq. (1) with respect to the volatility of the underlying asset (σ) and assuming that S_0 and X are independent of σ, we obtain:

$$\frac{\partial C_0}{\partial \sigma} = S_0 \cdot e^{-qT} n(d_1) \cdot \sqrt{T} \quad (2)$$

where $n(\cdot)$ is the normal probability density function and, therefore, $\frac{\partial C_0}{\partial \sigma}$ is always positive.

In R&D investments, the volatility of the underlying investment (σ) depends on both endogenous and exogenous uncertainty. Endogenous uncertainty stems from the intrinsic characteristics of the investment and can to some extent be reduced by firms' actions. For instance, Folta (1998) suggests that endogenous uncertainty can be reduced by learning. In contrast, exogenous uncertainty (i.e., uncertainty resulting from external factors) cannot, by definition, be controlled by firms.[3]

One source of exogenous uncertainty is EPU, which can be defined as uncertainty resulting from the effects of the actions or inactions of policymakers. Higher (lower) EPU increases (decreases) the volatility of the underlying asset. This in turn increases (decreases) the value of R&D growth options by enhancing (reducing) the probability of making large gains from investing in subsequent underlying projects. Yet it does not increase expected losses, since an initial outlay in R&D does not compel firms to undertake further investments. Accordingly, we state the following hypothesis:

H1. Higher (lower) EPU encourages (discourages) R&D investment.

Similarly, for a given S_0 and X, the first-order partial derivative of Eq. (1) with respect to the risk-free rate (r) is:

$$\frac{\partial C_0}{\partial r} = T \cdot X \cdot e^{-rT} N(d_2) \tag{3}$$

[3] This paper focuses on exogenous uncertainty. The relationship between endogenous uncertainty and R&D investment has been the subject of numerous studies. See, for instance, Cho and Lee (2020), Czarnitzki and Toole (2013, 2011), or Stein and Stone (2013).

which is always positive. This implies that an increase (decrease) in the monetary-policy rate should have a positive (negative) impact on the value of R&D investments. This leads us to posit our second hypothesis:

H2. Contractionary (expansionary) monetary policy encourages (discourages) R&D investment.

Finally, to elucidate the joint effect, we take the second-order mixed partial derivatives of Eq. (1) with respect to σ and r. Assuming that S_0 and X are independent of σ and r, we obtain the following expression:

$$\frac{\partial^2 c}{\partial r \partial \sigma} = -T \cdot X \cdot e^{-rT} \cdot n(d_2) \cdot \frac{d_1}{\sigma} \quad (4)$$

which is negative as long as $\frac{S_0}{X} > e^{-\left[\frac{1}{2}\cdot\sigma^2 + (r-q)\right]\cdot T}$. This condition holds for options that are not deeply out-the-money. Since out-the-money R&D projects are less likely to be undertaken, the negative impact is expected to predominate. Accordingly, we state our third and last hypothesis:

H3. The interaction between EPU and the monetary-policy rate exerts a negative influence on R&D investment.

3. Empirical analysis

In order to test our hypotheses, we estimate the following panel data model:

$$RD_{i,t} = \beta_1 + \beta_2 U_t + \beta_3 MPR_t + \beta_4 (U_t * MPR_t) + \boldsymbol{\Theta}' \boldsymbol{X}_{\boldsymbol{i,t}} + GDP_i + \omega_i + \nu_{i,t} \quad (5)$$

where i denotes the firm; t denotes the year; RD represents R&D investment; U is EPU; MPR is the monetary-policy rate; $\boldsymbol{X}$ is a vector of control variables at the firm level; $\boldsymbol{\beta}' =$

$(\beta_1 \quad \beta_2 \quad \beta_3 \quad \beta_4)$ and $\boldsymbol{\Theta}'$ are parameter vectors; GDP_t is a variable controlling for potential confounding macroeconomic factors[4]; ω represents firm fixed effects; and ν is the error term.

3.1. Sample and data sources

We build a database comprising 8,472 U.S. public firms for the period 2000-2019. Our sample covers all U.S. companies filing with the Securities and Exchange Commission, except financial firms. Data come from Refinitiv Eikon, www.policyuncertainty.com, and the Federal Reserve Bank of St. Louis.

We use three different proxies for R&D investment: the natural logarithm of R&D investment $(RD1_{i,t})$ (Czarnitzki and Toole, 2011); R&D investment over the sum of capital expenditures and R&D investment $(RD2_{i,t})$ (Peia and Romelli, 2020); and R&D investment scaled by total assets $(RD3_{i,t})$ (Zhang et al., 2020). EPU (U_t) is measured using the natural logarithm of the EPU index (Baker et al., 2016). The monetary-policy rate (MPR_t) is proxied by the fed funds rate (Bernanke and Blinder, 1992; Zhang et al., 2020). Following Peia and Romelli (2020), our model includes five firm-level control variables: total liabilities over total assets $(Leverage_{i,t})$, the logarithm of sales $(Sales_{i,t})$, the logarithm of total assets $(TA_{i,t})$, working capital normalized by total assets $(WC_{i,t})$, and capital expenditures scaled by total assets $(Capex_{i,t})$. Finally, we follow Gulen and Ion (2016) and introduce the growth rate of real GDP in our model (GDP_t) to control for macroeconomic factors. Table 1 shows the descriptive statistics for all the variables.

[4] Gulen and Ion (2016) suggest that introducing time fixed effects in a model with the EPU variable would absorb all the explanatory power of the latter. As a result, we do not include such effects. Nonetheless, we still need to control for the macroeconomic environment, so we include GDP_t in our model.

Table 1 – Summary statistics

Variable	Mean	Median	St. dev.	Maximum	Minimum	Observations
$RD1_{i,t}$	8.853	9.036	2.48	14.952	1.946	31,412
$RD2_{i,t}$	.5509	.06514	.03849	1	0	38,817
$RD3_{i,t}$	.1942	.0392	.4777	5.516	0	41,425
U_t	125.73	133.304	32.294	188.696	67.136	20
MPR_t	1.784	1.238	1.862	6.236	.0892	20
$Leverage_{i,t}$	2.06	.5534	7.837	112.6	.0016	72,699
$Sales_{i,t}$	11.302	11.845	3.42	17.738	1.609	64,279
$TA_{i,t}$	11.095	11.575	3.675	17.845	1.099	72,979
$WC_{i,t}$	-1.227	.1609	7.65	.95	-110.857	68,327
$Capex_{i,t}$	.0472	.0244	.068	.5238	0	69,648
GDP_t	2.105	2.29	1.429	4.13	-2.54	20

This table provides summary statistics for the natural logarithm of R&D investment $(RD1_{i,t})$, R&D investment over total investment $(RD2_{i,t})$, R&D investment over total assets $(RD3_{i,t})$, the EPU index (U_t), the fed funds rate (MPR_t), total liabilities over total assets $(Leverage_{i,t},)$, the logarithm of sales $(Sales_{i,t})$, the logarithm of total assets $(TA_{i,t})$, working capital over total assets $(WC_{i,t})$, capital expenditures over total assets $(Capex_{i,t})$, and the growth rate of real GDP (GDP_t). Observations below the 1st percentile and above the 99th percentile have been removed for all variables except for U_t, MPR_t, and GDP_t.

3.2. Results

Based on Eq. (5), we estimate three different models using each of the proxies for R&D investment. The estimation is performed using a fixed-effects estimator and Huber-White robust standard errors to overcome problems of heteroskedasticity (Davis and Karim, 2019). Results can be found in Table 2. EPU (U_t) is positive and highly significant in the three models, which seems to support **H1:** higher (lower) EPU increases (decreases) R&D investment. This result aligns with the evidence in Vo and Le (2017), who find a positive relationship between R&D investment and idiosyncratic uncertainty as measured by the standard deviation of the residuals from the regression model of stock returns on market returns.

Similarly, contractionary (expansionary) monetary policy (MPR_t) seems to have a positive (negative) impact on R&D investment, as stated in **H2**. This result is analogous to that in Dongyang et al. (2020). Specifically, they show that a hike in the fed funds rate results in an increase in both R&D investment and patents for Chinese firms. Lastly, the negative and significant coefficient of the interaction term supports **H3**: when high EPU and contractionary monetary-policy rate concur, the individual effect of these variables is partially offset.

Table 2 – Panel data regressions on R&D determinants

Dependent variable:	$\boldsymbol{RD1_{i,t}}$	$\boldsymbol{RD2_{i,t}}$	$\boldsymbol{RD3_{i,t}}$
U_t	.2260***	.0216***	.0764***
	(.031)	(.0063)	(.0109)
MPR_t	.1688***	.0065	.0922***
	(.0494)	(.0103)	(.0167)
$U_t * MPR_t$	-.0384***	-.0021	-.0205***
	(.0108)	(.0023)	(.0036)
Firm fixed effects	Yes	Yes	Yes
Macroeconomic controls	Yes	Yes	Yes
Firm-level controls	Yes	Yes	Yes
F-Statistic	323.75***	109.21***	36.7***
Within R-squared	.4098	.1571	.122
Observations	26,270	33,187	33,999

This table displays the estimates of Eq. (5) using a fixed-effects estimator. Dependent variables are the natural logarithm of R&D investment $(RD1_{i,t})$, R&D investment over total investment $(RD2_{i,t})$, and R&D investment over total assets $(RD3_{i,t})$. All models include firm fixed effects, the growth rate of real GDP to control for macroeconomic changes (GDP_t) and five firm-level variables: total liabilities over total assets $(Leverage_{i,t})$, the logarithm of sales ($Sales_{i,t}$), the logarithm of total assets ($TA_{i,t}$), working capital normalized by total assets ($WC_{i,t}$), and capital expenditures over total assets $(Capex_{i,t})$. *** indicates statistical significance at a 1% level. Huber-White, robust standard errors are reported in parentheses.

4. Conclusion

In this paper, we find that higher EPU and contractionary monetary policy do not deter corporate investment in R&D. On the contrary, they exert a positive influence that is only partially offset when both EPU and monetary-policy rate grow together. However, no less noteworthy is the other side of the lesson: an expansionary monetary policy aimed at encouraging corporate investment is likely to discourage innovation, particularly if served with decreasing EPU. One limitation of our study concerns the assumption that the value of the underlying asset (i.e., the potential capital investment; S_0) and the strike price (the cost of the capital investment; X) are independent of changes in EPU and the policy rate. Nonetheless, this assumption does not undermine our empirical results, which would remain in a more general setting that considered the effects of uncertainty and interest rates on the above variables.[5] Future research could explore the existence of firm-level asymmetries that moderate the relationship between EPU, monetary policy, and R&D investment.

Acknowledgements

We are grateful to the Spanish Ministry of Science and Innovation for its economic support under research project PID2020-114797GB-I00. As a recipient of a postdoctoral fellowship funded by the European Social Fund and the Regional Government of Castilla y León, Luis P. de la Horra is also grateful to these two institutions. Finally, we thank the associate editor and an anonymous reviewer for their helpful comments.

Funding

This work was supported by the Spanish Ministry of Science and Innovation under research project PID2020-114797GB-I00.

Declarations of interest

None

References

Aastveit, K.A., Natvik, G.J., Sola, S., 2017. Economic uncertainty and the influence of monetary policy. J. Int. Money Financ. 76, 50–67.

[5] We thank the Associate Editor for pointing out this limitation, which could provide an interesting avenue for future research.

https://doi.org/10.1016/j.jimonfin.2017.05.003

Baker, S.R., Bloom, N., Davis, S.J., 2016. Measuring Economic Policy Uncertainty. Q. J. Econ. 131, 1593–1636. https://doi.org/10.1093/qje/qjw024

Bernanke, B.S., Blinder, A.S., 1992. The Federal Funds Rate and the Channels of Monetary Transmission. Am. Econ. Rev. 82, 901–921.

Black, F., Scholes, M., 1973. The Pricing of Options and Corporate Liabilities. J. Polit. Econ. 81, 637–654. https://doi.org/10.1086/260062

Boivin, J., Kiley, M.T., Mishkin, F.S., 2010. How Has the Monetary Transmission Mechanism Evolved Over Time? Handb. Monet. Econ. 3, 369–422. https://doi.org/10.1016/B978-0-444-53238-1.00008-9

Cho, S.-H., Lee, J., 2020. Estimating the uncertainty–R&D investment relationship and its interactions with firm size. Small Bus. Econ. https://doi.org/10.1007/s11187-020-00346-8

Czarnitzki, D., Toole, A.A., 2013. The R&D Investment-Uncertainty Relationship: Do Strategic Rivalry and Firm Size Matter? Manag. Decis. Econ. 15–28. https://doi.org/10.1002/mde.2570

Czarnitzki, D., Toole, A.A., 2011. Patent Protection, Market Uncertainty, and R&D Investment. Rev. Econ. Stat. 93, 147–159. https://doi.org/10.1162/REST_a_00069

Davis, E.P., Karim, D., 2019. Exploring short- and long- run links from bank competition to risk. Eur. Financ. Manag. 25, 462–488. https://doi.org/10.1111/eufm.12176

de la Horra, L.P., Perote, J., de la Fuente, G., 2021. Monetary Policy and Corporate

Investment: A Panel-data Analysis of Transmission Mechanisms in Contexts of High Uncertainty. Int. Rev. Econ. Financ. 75, 609–624. https://doi.org/10.1016/j.iref.2021.04.035

Dixit, A.K., Pindyck, R.S., 1995. The options approach to capital investment. Harv. Bus. Rev. 105–115. https://doi.org/10.1016/b978-0-7506-7009-8.50024-0

Folta, T.B., 1998. Governance and uncertainty: the trade-off between administrative control and commitment. Strateg. Manag. J. 19, 1007–1028. https://doi.org/10.1002/(SICI)1097-0266(1998110)19:11<1007::AID-SMJ999>3.0.CO;2-8

Gulen, H., Ion, M., 2016. Policy Uncertainty and Corporate Investment. Rev. Financ. Stud. 29, 523–564. https://doi.org/10.1093/rfs/hhv050

Kester, C.W., 1984. Today's options for tomorrow's growth. Harv. Bus. Rev. 62, 153–160.

Kraft, H., Schwartz, E., Weiss, F., 2018. Growth options and firm valuation. Eur. Financ. Manag. 24, 209–238. https://doi.org/10.1111/eufm.12141

Merton, R.C., 1973. Theory of Rational Option Pricing. Bell J. Econ. Manag. Sci. 4, 141–183. https://doi.org/10.2307/3003143

Mitchell, G.R., Hamilton, W.F., 1988. Managing R&D as A Strategic Option. Res. Technol. Manag. 31, 15–22. https://doi.org/10.1080/08956308.2007.11657429

Moran, P., Queralto, A., 2018. Innovation, productivity, and monetary policy. J. Monet. Econ. 93, 24–41. https://doi.org/10.1016/j.jmoneco.2017.10.006

Peia, O., Romelli, D., 2020. Did financial frictions stifle R&D investment in Europe during the great recession? J. Int. Money Financ. 102263. https://doi.org/10.1016/j.jimonfin.2020.102263

Stein, L.C.D., Stone, E., 2013. The Effect of Uncertainty on Investment: Evidence from Options. SSRN Electron. J. https://doi.org/10.2139/ssrn.1649108

Suh, H., Yang, J.Y., 2021. Global uncertainty and Global Economic Policy Uncertainty: Different implications for firm investment. Econ. Lett. 200, 109767. https://doi.org/10.1016/j.econlet.2021.109767

Vo, L. Van, Le, H.T.T., 2017. Strategic growth option, uncertainty, and R&D investment. Int. Rev. Financ. Anal. 51, 16–24. https://doi.org/10.1016/j.irfa.2017.03.002

Yan, Z., 2018. Economic Transformation, Monetary Policy and Enterprise R&D Investment, in: Proceedings of the 2018 International Conference on Economy, Management and Entrepreneurship (ICOEME 2018). Atlantis Press, Paris, France. https://doi.org/10.2991/icoeme-18.2018.71

Zhang, D., Guo, Y., Wang, Z., Chen, Y., 2020. The impact of US monetary policy on Chinese enterprises' R&D investment. Financ. Res. Lett. 35, 101301. https://doi.org/10.1016/j.frl.2019.09.016

Highlights

- We empirically analyze the influence of EPU and monetary policy on R&D investment.
- We draw upon the Black-Scholes-Merton model to derive testable hypotheses.
- EPU has a positive impact on R&D investment.
- Contractionary monetary policy encourages firms to invest in R&D projects.
- The interaction between EPU and monetary policy negatively affects R&D investment.