1 Introduction

The UK has been experiencing a prolonged period of stagnated business investment. Fig.1 illustrates business investment over 1992-2016 and shows that investment has been persistently below the pre-crisis trend since 2007.

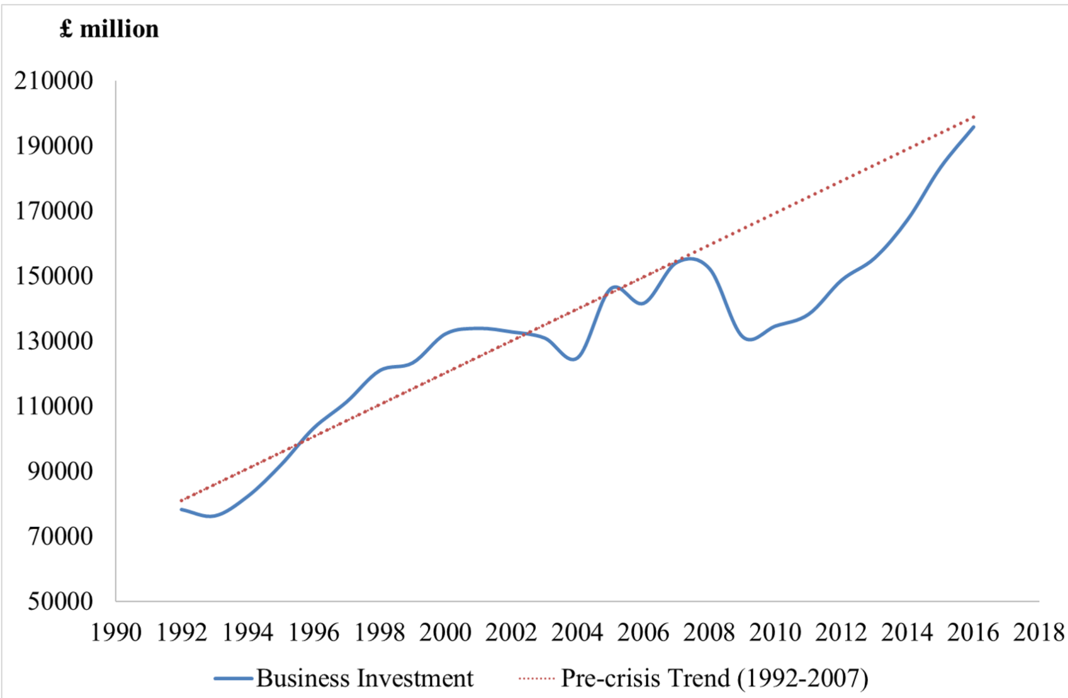

Figure 1: UK business investment. Author's calculation based on data from the ONS.

Hayashi (1982) proves that the ratio of the market value to the replacement cost of capital, average Q, is positively related to the investment rate insofar that market valuation captures information regarding expected profitability. Theoretically, the weakness of investment arises from either high cost of capital or low profitability. However, neither of the two arguments provides satisfactory explanation (e.g., Gutiérrez & Philippon (2017)). The rapid growth of intangible economies leads to a significant increase in investment on intangible capital such as R&D and patents (Haskel & Westlake (2018)). In recent years the literature shows that sluggish fixed investment results from firms substituting physical capital with intangibles. Gutiérrez & Philippon (2017) show that intangibles partially explain the under-investment trend at the industry-level. Alexander & Eberly (2018) emphasize that the declining physical investment is due to capital composition shifts from physical capital to intangible capital. Crouzet & Eberly (2019) find that the investment gap is reduced at both the firm-level and industry-level by accounting for the rise in intangibles. As shown by Crouzet & Eberly (2019), omitting intangibles in the Q-model of investment would result in underestimation of capital stock. Furthermore, Q would tend to overestimate the marginal value of capital. Consequently, the measurement of the response of (physical) investment to Q is biased in the absence of intangibles.[1]

However, current research is largely confined to the US market. To fill this void, this paper investigates the reason behind the UK under-investment gap from the perspective of rising intangibles. This paper follows the work of Crouzet & Eberly (2019) which consider intangible capital as an omitted factor to explain the US investment shortfall. Building on the analysis of Crouzet & Eberly (2019), this paper further explores the effects of intangibles on firm-level fixed investment in three subpeiords and subsamples with different firm characteristics. This paper presents empirical evidence suggesting that the transformation towards intangibles in the economy provides a key component of an explanation of the UK under-investment puzzle. For example, Fig.2 demonstrates that there have been negative time effects conditional on Q which started from 2002 and the gap further increased since the 2008 financial crisis. However, in the presence of intangibles, the under-investment gap since 2002 can be reduced by approximately 70%. This finding is considerably larger than that of Crouzet & Eberly (2019) which state that the US firm-level investment gap only decreased one quarter by adjusting for intangibles.

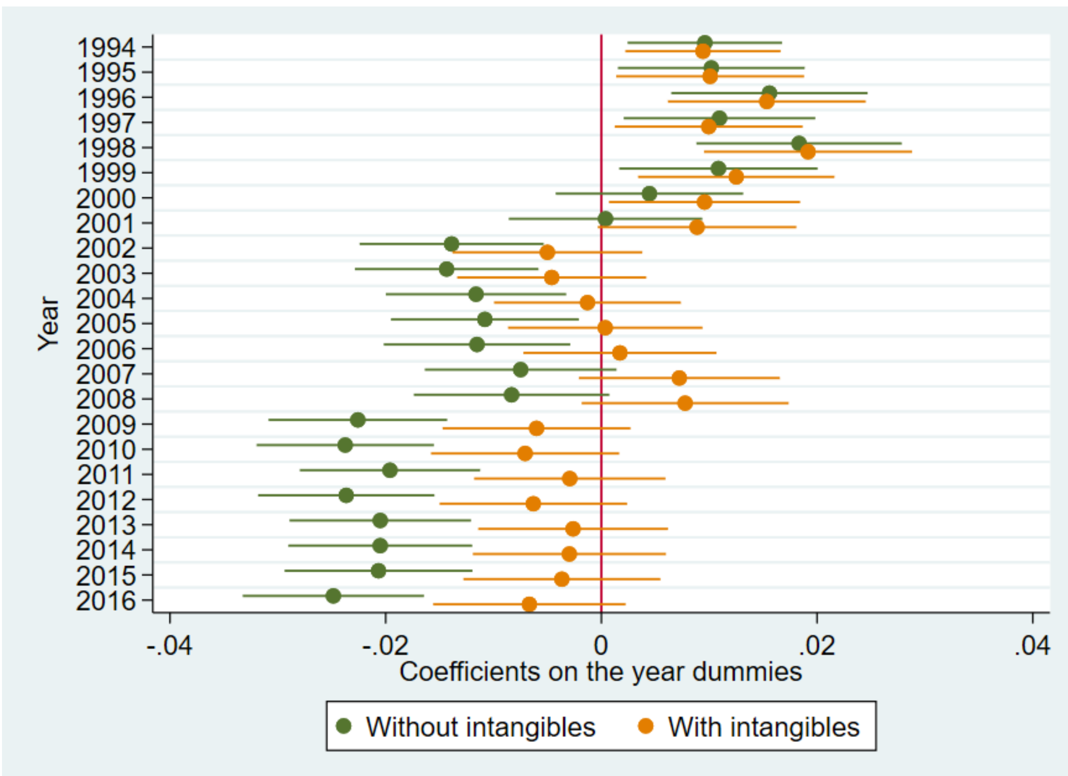

Figure 2: Under-investment gap depicted by the time fixed effects from panel regressions of investment on the beginning-of-period Q. The data source is Datastream.

The contribution of this paper is threefold: First, this paper confirms that the UK under-investment puzzle can be explained by intangibles at the firm-level. The negative

[1]For more details, see Crouzet & Eberly (2019).

association between intangibles and fixed investment is larger for firms with higher leverage, lower tangibility and lower labour productivity. Second, this analysis contributes to distinguish the relationship between intangibles and under-investment gap across three subperiods. Specifically, the weak investment trend originated from 2002, which is long before the onset of the 2008 financial crisis. Whilst the under-investment gap since the financial crisis still exists, the results suggest that adjusting for intangibles diminishes the under-investment gap by approximately 70%. Finally, the efficacy of conventional monetary policy to boost investment can decline due to being underpinned by the zero lower bound and characteristics of intangibles, e.g. low collateralizability and low interest rate sensitivity. This paper provides policy implications by highlighting the importance of utilising unconventional policies to stimulate investment.

2 Data

The sample consists of 620 UK non-financial firms from Datastream. The dataset of annual observations is from 1992-2016. To mitigate potential survivor bias, selected firms have no fewer than four consecutive years of data on any variables. Firms with a negative value of investment and Q are excluded. The data is winsorized at the 1 and 99 percentiles to reduce outliers.

The baseline empirical specification is as follows:

$$Investment_{i,t} = \beta_1 Investment_{i,t-1} + \beta_2 Q_{i,t-1} + \beta_3 Intangibles_{i,t-1} + \lambda \Gamma'_{i,t-1} + \alpha_t + \alpha_i + \varepsilon_{i,t} \quad (1)$$

where $Investment_{i,t}$ is capital expenditures (WC04601)[2] scaled by the beginning-of-period total assets (WC02999). $Investment_{i,t-1}$ is included to allow for adjustment costs. Following Chung & Pruitt (1994), $Q_{i,t-1}$ (168E) is the ratio between the sum of the market value of equity plus book value of preferred stock and debt to book value of total assets. $Intangibles_{i,t-1}$ are the ratio of intangible assets (WC02649) to total assets. Following Lin et al. (2018), I control for cash flow defined as the ratio of funds from operations (WC04201) to total assets and firm size proxied by the natural logarithm of sales (WC01001) via a vector of firm-level variables, $\Gamma_{i,t-1}$. The regression framework allows for time and firm fixed effects through α_t and α_i, respectively. $\varepsilon_{i,t}$ is an idiosyncratic error term.

3 Evidence

Table 1 presents the panel regression results obtained using three estimators: pooled OLS, fixed effects and system GMM (Arellano & Bover (1995) and Blundell & Bond (1998)). As shown in columns 1-3, the coefficient estimates for intangibles are negative and statistically significant

[2]Datastream code.

at the 1% level. In particular, the largest magnitude of coefficient is reported by the system GMM estimator. Columns 4-6 mimic the analysis of columns 1-3 whilst including firm controls. The statistically significant negative association between intangibles and fixed investment holds across the three estimators, indicating the explanatory power of intangibles are not diminished by accounting for controls. The R^2 of fixed effects regression in column 5 is 5.11% lower than that of column 2 without controls.[3] Column 6 shows that a one-unit increase in intangibles is associated with a decrease in fixed investment by 0.0463-unit on average ceteris paribus. In contrast to Gutiérrez & Philippon (2017) which show that intangibles are not significant at the firm-level, Table 1 suggests that intangibles are negatively associated with the firm-level investment at the 1% significance level across various estimators.

Table 1: Panel regressions: three estimators

	(1)	(2)	(3)	(4)	(5)	(6)
$Investment_{i,t-1}$	0.5808***	0.3310***	0.3700***	0.5674***	0.3190***	0.3645***
	(0.0217)	(0.0228)	(0.0252)	(0.021)	(0.0228)	(0.0254)
$Q_{i,t-1}$	0.0022***	0.0050***	0.0028**	0.0029***	0.0050***	0.0033***
	(0.0005)	(0.0006)	(0.0011)	(0.0005)	(0.0006)	(0.0011)
$Intangibles_{i,t-1}$	-0.0296***	-0.0187***	-0.0378***	-0.0306***	-0.0202***	-0.0463***
	(0.0024)	(0.0050)	(0.0073)	(0.0024)	(0.0051)	(0.0074)
$Cash\ flow_{i,t-1}$				0.0273***	0.0285***	0.0337***
				(0.0054)	(0.0065)	(0.0123)
$Size_{i,t-1}$				-0.00003	-0.0044***	-0.0010
				(0.0002)	(0.0012)	(0.0011)
Observations	10534	10534	10534	10501	10501	10501
Firms	620	620	620	620	620	620
Estimation Method	OLS	FE	Sys. GMM	OLS	FE	Sys. GMM
R^2	0.4523	0.4178		0.4555	0.3667	
AR(2) p-value			0.381			0.477
Hansen-test p-value			0.255			0.101

Notes: This table presents the results from three estimators: pooled OLS, fixed effects and system GMM. The dependent variable is $Investment_{i,t}$. Year dummies are included in all specifications. Robust standard errors are in parenthesis. Hansen-test of the over-identifying restrictions is under the null that the instruments as a group are exogenous. Lagged endogenous and predetermined variables are used as instruments. ***, **, * denote significance at the 1%, 5% and 10% level, respectively.

Conceivably the effects of intangibles on fixed investment vary across the three subperiods identified in Fig.2. Table 2 investigates this time-varying effect by including the interactions of

[3] Hence the controls are not included in the subsequent estimations.

intangibles with the subperiod dummies. The remaining analysis employs system GMM estimator which corrects for the endogeneity and heterogeneity bias (Blundell & Bond 1998) thus providing the most robust estimates. Column 1 of table 2 shows that the negative impact of intangibles is significant at the 1% level throughout the three subperiods. To compare the magnitude of the effects of intangibles on fixed investment across different subperiods, column 2 presents the standardized coefficients. In particular, the standardized coefficient estimate pertaining to intangibles in $subperiod_3$ is the largest among three subperiods, which indicates that a one standard deviation increase in intangibles leads to a 0.135 standard deviation decrease in fixed investment ceteris paribus. This result is consistent with Fig.2 which shows that the size of the under-investment gap can be largely reduced by controlling for intangibles over 2009-2016. It is noteworthy that the US (e.g., Alexander & Eberly (2018)) and the UK share the similar pattern of the under-investment gap characterised by three subperiods.

Table 2: Regression with subperiod dummies

	(1)	(2)
$Investment_{i,t-1}$	0.3704***	0.393
	(0.0250)	
$Q_{i,t-1}$	0.0027**	0.0731
	(0.0011)	
$Intangibles_{i,t-1} * subperiod_1$	-0.0444***	-0.0452
	(0.0117)	
$Intangibles_{i,t-1} * subperiod_2$	-0.0477***	-0.115
	(0.0059)	
$Intangibles_{i,t-1} * subperiod_3$	-0.0410***	-0.135
	(0.0041)	
Observations	10534	
Firms	620	
AR(2) p-value	0.390	
Hansen-test p-value	0.285	

Notes: Column 1 reports system GMM estimation results obtained including the interactions of intangibles with the subperiod dummies. $Subperiod_1$, $subperiod_2$, $subperiod_3$ range from 1992-2001, 2002-2008 and 2009-2016, respectively. Column 2 reports corresponding standardised coefficients.

Table 3 explores the robustness by partitioning firms based on the medians of: leverage, total liabilities (WC03351) scaled by total assets; tangibility, property-plant-and-equipment (WC02501) scaled by total assets; and labour productivity, the natural logarithm of sales per employee (WC07011). As shown in columns 1 and 2, the coefficient of intangibles for firms with higher and lower leverage is -0.0399 and -0.0316, respectively. Whilst higher leverage does not guarantee that firms are financially constrained per-se, it is a sign of difficulty in financing projects with external funds. The results demonstrate that intangibles have a more statistically and economically significant effect on firms subject to higher financial constraints. Since intangibles interact less with interest rate changes than physical capital, it is important for policymakers to implement supportive policies instead of relying on traditional monetary policy to promote business investment. Columns 3 and 4 show that the coefficient estimates for intangibles are significantly negative at the 1% level across the tangibility subsamples, albeit the estimated coefficient for firms with lower tangibility is 0.4% greater than that of higher tangibility. As intangible-intensive firms are usually associated with low asset tangibility, this result is broadly consistent with Crouzet & Eberly (2019) which relate the weakness of the US physical investment to the rise in intangible capital. In column 5, the negative relationship between intangibles and fixed investment holds up for firms with higher labour productivity, which is statistically significant at the 1% level. Column 6 returns a negative coefficient on intangibles for firms with lower labour productivity of similar magnitude for the full-sample result in column 3 of Table 1.

Table 3: Robustness checks

	Leverage		Tangibility		Labour Productivity	
	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)
$Investment_{i,t-1}$	0.3818***	0.3342***	0.4395***	0.3281***	0.3787***	0.3471***
	(0.0469)	(0.0418)	(0.0329)	(0.0450)	(0.0379)	(0.0347)
$Q_{i,t-1}$	0.0029	0.0024	0.0033**	0.0029*	0.0019	0.0020
	(0.0020)	(0.0019)	(0.0015)	(0.0017)	(0.0015)	(0.0016)
$Intangibles_{i,t-1}$	-0.0399***	-0.0316**	-0.0391***	-0.0431***	-0.0344***	-0.0381***
	(0.0101)	(0.0123)	(0.0076)	(0.0112)	(0.0115)	(0.0101)
Observations	5177	5357	5909	4625	5231	5303
Firms	310	310	310	310	311	309
AR(2) p-value	0.290	0.586	0.491	0.136	0.367	0.637
Hansen-test p-value	0.362	0.286	0.117	0.128	0.129	0.114

Notes: System GMM estimation results for firm groups split by higher and lower leverage, tangibility and labour productivity.

4 Conclusion

This paper documents that intangibles are negatively associated with firm-level investment and explain a considerable amount of the UK under-investment gap. The findings are consistent across subperiods and subsamples.

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