What explains patenting behaviour during Britain's Industrial Revolution?

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Abstract

A recent re-evaluation of patenting during the British Industrial Revolution argues patentees were responsive to demand-side conditions. This view does not consider supply-side factors, such as a patentee's skill or access to financial resources, as an alternative mechanism. I exploit a rich dataset of patentee occupations to investigate the role a patentee's economic or social background played in their patenting behaviour. I find skilled patentees were intensive users of the patent system and frequently patented more economically valuable inventions. I also find patent value mattered more than patentee skill for patent extension, which likely indicates the existence of financiers willing to back the acquisition of patents for valuable inventions. The composition of Britain's patentees, and their use of the system, reasonably relates to the value of the inventions they sought to protect.

Keywords: Incentives, Innovation, Occupations, Patent Institutions, Patent Value, Industrial Revolution

JEL Codes: N74, 031, 034.

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1 Introduction

The Industrial Revolution is one of the most important events in history. Economic historians agree the revolution was a direct result of sustained innovative activity in Britain during the late eighteenth century (Landes, 2003; Allen, 2009; Mokyr, 2009). But, explanations for the rise of innovative activity remain contested; why did inventors choose to invent? The debate focuses on whether invention is economically motivated – the demand-side (Schmookler, 1966; Allen, 2009), or a result of inventors possessing innate skills or specialist knowledge in the art of innovation – the supply-side (Mokyr, 2009; Kelly et al., 2014). Settling the debate necessitates a better understanding of invention in eighteenth century Britain, such as who the inventors were, what technologies they were inventing, and what factors motivated their behaviour.

Several contributions to the invention debate exploit Britain's rich patent data (e.g. Dutton, 1984; Moser, 2005; Greasley and Oxley, 2007; Khan, 2018; Cox, 2020). Principal among these contributions is the work of Sean Bottomley, who exploits the unique structure of Britain's patent system to re-evaluate the debate (Bottomley, 2014a,b). The United Kingdom of Great Britain and Ireland comprised three distinct patent jurisdictions: England, Ireland, and Scotland. It was also the most expensive patent system amongst contemporaries (Hancock, 1850).[1] Britain's system, Bottomley argues, aids our understanding of whether inventors were responsive to market opportunities. He argues Irish and Scottish patents were an extension of their English counterpart, and where an inventor chose to 'extend' their patent reveals their motivations: patenting in both England and Scotland, for example, was a response to the relative market opportunities of the patented invention.

Bottomley's work emphasises demand-side conditions, but does not consider the role of supply-side factors, which arguably matter for the following reasons. First, as Bottomley does note, patenting was expensive. The average cost of an English patent was approximately £100 in the 1840's, while a Scottish patent cost £75, and an Irish patent cost £135 (Dutton, 1984; MacLeod, 1998; Bottomley, 2014b). Costly patents are

[1] See Appendix A for a brief overview of the background of the patent system and its costs.

an effective barrier to entry against inventors lacking financial resources, regardless of their invention's economic value (MacLeod et al., 2003). Second, patentees were a heterogeneous group of inventors who exploited their patents differently (MacLeod, 1998; Allen, 2014); their patent's value is unlikely to solely explain extension. Third, market opportunities may motivate patentees, but that does not guarantee they will produce a valuable, patentable invention. Observing patentee occupations can help address these concerns; occupations likely correlate with a patentee's ability to finance their patents, their desire to use the patent system, and their invention's value.

MacLeod (1998) provides an early discussion of patentee occupations during the Industrial Revolution. The composition of Britain's patentees across the eighteenth century reflected the industrialisation of the patent system. 'Industrial producers', who include artisans, craftsmen, and engineers, were increasingly patenting during the Industrial Revolution and arguably considered patents as valuable assets (MacLeod, 1998). The industrial producers are also linked with a small elite that Mokyr (2005) calls the 'upper tail of human capital', who he argues were crucial drivers of Britain's technical change. At the same time, Khan (2005) argues that Britain's high patent fees made the system undemocratic in its usage, by restricting access to the elite but also favouring the patenting of high-value, capital-intensive inventions. However, patentee's occupations are not clearly linked with their patenting activity: to what extent can a patentee's economic background explain their behaviour?

I observe the entire population of Britain's patentees, 1700-1841, to better understand their patenting behaviour. My analysis exploits Britain's rich patentee occupation data to focus on the role of supply-side factors in patenting activity. First, I examine the composition of Britain's patentees using the HISCO-HISCLASS schema, which classifies patentees into skill-based ranks. The schema provides a useful framework to analyse how patentees used the patent system and whether this differed by occupational status. Second, I test whether patentee skills correlate with the value of their patented inventions. Patent value is linked to patent extension, as patentees sought to exploit local market opportunities (Bottomley, 2014a). Should patent value also correlate with patentee skills, then the decision to extend protection, and to patent, likely concerns supply-side factors.

I find both demand-side and supply-side factors matter when explaining patentee behaviour. Higher-skilled patentees were intensive users of the patent system and frequently protected economically valuable inventions. But, skill is only weakly correlated with patent extension. Patent value, by contrast, reports a strong correlation. The value of an invention, rather than the skill of their holder, appears to be the more important factor motivating patentees. This finding highlights the likely existence of financiers. Credit-constrained inventors with valuable innovations may seek the backing of a financier, who is arguably likely to fund the acquisition of a patent as a means of protecting the invention's returns. The prevalence of skilled patentees may reflect their ability to produce valuable innovations capable of attracting a financier.

2 Data

My data are the entire population of English patents granted between 1700 and 1841, collected from Woodcroft (1854). English patents are matched with their Irish and Scottish patents using data from Bottomley (2014a). The information contained in the final dataset includes the name of the patentee(s), the year their patent was granted, their occupation, their residence, and their patent's title.[2]

To capture a patent's value, I use the popular Woodcroft Reference Index (WRI) (Nuvolari and Tartari, 2011) and the more recent Bibliographic Composite Index (BCI) (Nuvolari et al., 2021). The WRI counts the number of references made to a patent in the contemporary trade and scientific literature in England, capturing its economic and technical importance. Counting the references is useful to discern a patent's *ex post* realised value. Because the number of references per patent artificially increases over time, I weight the total references a patent receives by the mean number of references received by all patents in a single time cohort. The time cohorts, adopted from Nuvolari and Tartari (2011), are as follows: 1702–1721, 1722–1741, 1742–1761, 1762–1781, 1782–1801, 1802–1811, 1812–1821, 1822–1831, 1832–1841. The BCI, by contrast, is a composite

[2]The dataset, including occupational data, is published at Billington (2021).

index combining the WRI metric with bibliographic measures of a patent's value and biographical dictionaries of a patentee's importance to technological progress.

2.1 Occupation Data

2.1.1 Classifying Occupations

Britain's patent records include a patentee's stated occupation. On their own, occupational titles are not immediately comparable nor indicative of skill. It is therefore necessary to apply a classification schema which groups similar occupations based on skill or social status for the purposes of comparative analysis. To do so, I adopt the popular HISCO-HISCLASS framework.

The Historical International Standard Classification of Occupations (HISCO) is a class scheme designed to facilitate comparisons of occupation titles over space and time (Van Leeuwen et al., 2002). The Historical International Social Class Scheme (HISCLASS) compliments HISCO, by classifying occupations by their social status or prestige (Van Leeuwen and Maas, 2011). HISCLASS places occupations into one of twelve social classes, based on: whether occupations engage in manual work; the level of skills associated with that occupation; whether the occupation requires supervision; and the occupation's economic sector (Van Leeuwen and Maas, 2011).

The HISCO-HISCLASS framework features prominently in studies of human capital during Britain's industrialisation. For example, the schema has been used to: test the de-skilling hypothesis (de Pleijt and Weisdorf, 2017); study human capital formation in response to technological change (de Pleijt et al., 2020); study wages of unskilled women in England (Humphries and Weisdorf, 2015); and observe child quantity-quality trade-off on human capital outcomes for children (Klemp and Weisdorf, 2019). The emphasis on English occupations spanning the Industrial Revolution supports my application of HISCO-HISCLASS to study Britain's patentees.

Before applying HISCLASS, several considerations concerning patentee occupations need discussed. First, it is unclear whether the named patentee was the inventor or a financial backer (MacLeod, 1998); for patents with multiple named persons it is not clear who, if any, were the inventor. As the patent is my unit of analysis, it is necessary to ascribe each patent to a single named person who is also the likely inventor (MacLeod, 1998). I follow MacLeod's approach when dealing with the occupations of multiple named patentees, by giving preference to a trade over status or mercantile titles, and giving preference to a non-London resident where named patentees have similar occupations.

Second, many patentees erroneously list a status, such as 'gentleman' or 'esquire', instead of their occupation (MacLeod, 1998). Though several patentees list an occupation alongside their status, the rest do not. I therefore assume anyone listing a status was a true gentlemen, following (MacLeod, 1998), and control for them using a dummy variable.

Third, 'patent agent' is a regularly appearing title. Patent agents were often workers within the patent office who used their patent expertise to provide services for prospective patentees (Bottomley, 2014b). One important service was for the patent agent to patent in their name but on an applicant's behalf. There is no way of checking whether patents held by a patent agent were their own. Therefore, I assume any patents belonging to patent agents were held on behalf of a client, and control for them separately.

Fourth, several patentees list different occupations across their patent grants. Some changes in occupation are within similar occupational groups, while others are across them. Whether this reflects changes in the patentee's human capital is unclear, though not unlikely; progressing from a millwright to an engineer, for example, likely reflects a change in human capital. Since it is not possible to check whether changes in occupational titles were arbitrary or indicative of human capital formation, I treat a patentee's listed occupation as indicative of their human capital or access to financial resources at that moment in time.

2.1.2 Occupation Statistics

Table 1 shows the distribution of unique patentees by their occupation's HISCLASS codes. For each social status category, the top-five most common occupations relating to that category are listed, alongside the class's skill ranking from Van Leeuwen and Maas (2011).[3] The table shows a correlation between social status and patentee

[3]Appendix B provides a discussion of how representative these patentees were of the general

Table 1: HISCLASS distribution for unique patentees, 1700-1841

HISCLASS	Skill	Occupations	Patentees
1 - Higher Managers	High	Gentleman, Esquire, Manufacturer, Manager, Officer	1,881
2 - Higher Professionals	High	Engineer, Chemist, Physician, Lawyer, Professor	800
3 - Lower Managers	Medium	Wharfinger, Overlooker, Contractor, Colourman, Wholesaler	17
4 - Lower Professionals, and Clerical and Sales Personnel	Medium	Merchant, Draughtsman, Surveyor, Agent, Dealer	719
5 - Lower Clerical and Sales Personnel	Low	Clerk, Pawnbroker, Warehouseman	51
6 - Foremen	Medium	Master Mariner, Foremen, Master Artisans	25
7 - Medium-skilled Workers	Medium	Watch maker, Instrument maker, Gun maker, Machine maker, Brass founder	1,213
8 - Farmers and Fishermen	Medium	Farmer, Planter, Yeoman, Grazier, Gamekeeper	45
9 - Lower-skilled Workers	Low	Spinner, Builder, Weaver, Dyer, Frame smith	486
10 - Lower-skilled Farm Workers	Low	NA	-
11 - Unskilled Workers	Unskilled	Packer, Mariner, Toy Maker, Candle Maker, Dresser	24
12 - Unskilled Farm Workers	Unskilled	Gardener, Seedsman, Training Groom	9

Notes: The table shows the distribution of unique patentee's occupations by assigned HISCLASS codes. Each HISCLASS group is also assigned to one of four skill categories based on the definitions from Van Leeuwen and Maas (2011). Each category reports the top 5 most commonly appearing occupations in no particular order.

representation. Higher social status patentees were more common in the data than lower status ones; the largest single group are Higher Managers, accounting for 1,881 patentees or approximately 36 per cent of all patentees. The next largest group are Medium-skilled Workers, comprising 1,213 patentees or 23 per cent of all patentees. The Unskilled comprise the fewest unique patentees; only 33 patentees report an Unskilled occupation, reflecting less than one per cent of all patentees.

Table 2 reports the patent-to-patentee ratio by HISCLASS category.[4] The most active patentees were Higher Professionals (2.3 patents), Higher Managers (1.8 patents), and Medium-skilled Workers (1.7 patents). By contrast, the least active patentees were Unskilled Workers (1.2 patents) and Foremen (1.3 patents). The prominence of specific

population. The historical evidence suggests that patentees were significantly over-represented by higher-skilled occupations, while under-represented by lower-skilled and likely poorer workers.

[4]Hanlon (2021) reports a similar table showing the ratio of patents-to-patentees by specific occupational groups, to elicit the patenting intensity of Engineers. My approach is complementary, by reporting the patenting ratio using a hierarchical occupation classification system, which highlights how patent intensity changes with skill and social status.

Table 2: Patent-to-patentee ratios by HISCLASS group, 1700-1841

HISCLASS	**Patentees**	**Patents**	**Ratio**
High-skilled			
1 - Higher Managers	1,881	3,419	1.82
2 - Higher Professionals	800	1,859	2.32
Medium-skilled			
3 - Lower Managers	17	24	1.41
4 - Lower Professionals, and Clerical and Sales Personnel	719	1,165	1.62
6 - Foremen	25	32	1.28
7 - Medium-skilled Workers	1,213	2,066	1.70
8 - Farmers and Fishermen	45	71	1.58
Low-skilled			
5 - Lower Clerical and Sales Personnel	51	80	1.57
9 - Lower-skilled Workers	486	737	1.52
10 - Lower-skilled Farm Workers	0	0	-
Unskilled			
11 - Unskilled Workers	24	28	1.17
12 - Unskilled Farm Workers	9	15	1.67

Notes: The table shows the number of unique patentees by occupational grouping, as well as how many patents were granted to that grouping. 'Ratio' is the patent-to-patentee ratio, calculated by dividing the number of patents by the number of unique patentees within each HISCLASS group.

social status groups, and their higher propensity to obtain multiple patents, strongly suggests that these patentees viewed patents as valuable assets. The costs associated with patenting, however, made intensive use of the system very expensive; intensive users likely had access to substantial financial resources to obtain their patents.

The representation of patentee occupations relative to the general population are reported in table 3. The table represents English occupations versus patentee occupations using social tables constructed in Allen (2019).[5] Allen reports social tables for five different years covering the Industrial Revolution: 1688, 1759, 1798, 1846, and 1867. My comparison of patentee occupations will focus only on two years spanning my study: 1798, and 1846.[6] For the patent data, I observe the distribution of patentees for a 10-year interval covering Allen's time periods; for 1798, the patent data cover 1790–1801, while 1846 covers patents from 1840–1851. Finally, only those patentees who could be assigned to Allen's social groups are observed.

The estimates show the significant over-representation of higher social status

[5] See Appendix B for a description concerning the construction of the social tables using the patent data.

[6] I exclude 1759 because there are too few patentees for that period.

Table 3: Comparison of patentees versus the population using Allen's social groups

	1798		1846	
Class	Allen	Patentees	Allen	Patentees
Landed Classes	1.3%	19.89%	1.3%	20.50%
Bourgeoisie	3.2%	12.77%	8.6%	22.03%
Lower Middle Class	8.6%	39.23%	15.4%	38.76%
Farmers	10.8%	1.28%	5.7%	0.92%
Workers	61.1%	12.04%	61.4%	7.43%
Paupers	14.9%	0.00%	7.6%	0.00%
Total	2,951,687	548	4,228,393	3,581

Notes: For 1798, I include patents granted between 1790 and 1801. For 1846, I include patents granted between 1840 and 1851. I am able to classify 90% of patentee occupations using Allen's social tables. Consequently, there will be some error in the estimates, but any errors are unlikely to undermine the conclusions which can be drawn from the table.

Source: Allen (2019) and author's calculations using Woodcroft (1854).

occupations, and the significant under-representation of poorer and possibly less skilled persons. The Landed classes accounted for approximately 1.3 per cent of the population in both 1798 and 1846, while their share of patents was approximately 20 per cent. Bourgeoisie persons are also over-represented, though their representation increases from 1798 to 1846; their population share rose from 3.2 per cent to 8.6 per cent, while their share of patents granted rose from 14.93 per cent to 22.19 per cent. The Lower Middle Class held approximately 39 per cent of patents in both periods, yet their share of the population rose from 8.6 per cent to 15.4 per cent. By contrast, Workers are drastically under-represented. Despite accounting for more than 60 per cent of the population, they held only 12 per cent of all patents granted around 1798 and 7.43 per cent around 1846. Finally, paupers are completely absent from the patent records.

Table 4 reports patent extension by HISCLASS group. There is little variation across social status groups in the propensity to extend protection to specific jurisdictions. However, there are notable observations. First, patentees rarely sought Irish extension by itself. Second, High-skilled patentees had the highest propensity to extend patent protection to Scotland or both Scotland and Ireland. Third, Medium-skilled Workers report one of the lowest propensities to patent in multiple jurisdictions. Fourth, Low-skilled patentees extended protection just as frequently as Medium-skilled

Table 4: Patent extension by HISCLASS grouping, 1700-1841

Class	**Scotland**	**Ireland**	**Both**
High-skilled			
1 - Higher Managers	506 (14.80%)	60 (1.75%)	340 (9.94%)
2 - Higher Professionals	355 (19.10%)	33 (1.78%)	188 (10.11%)
Medium-skilled			
3 - Lower Managers	4 (16.67%)	1 (4.17%)	2 (8.33%)
4 - Lower Professionals, and Clerical and Sales Personnel	170 (14.59%)	21 (1.80%)	101 (8.67%)
6 - Foremen	2 (6.25%)	0 (0.00%)	3 (9.38%)
7 - Medium-skilled Workers	242 (11.71%)	15 (0.73%)	125 (6.05%)
8 - Farmers and Fishermen	7 (9.86%)	0 (0.00%)	2 (2.82%)
Low-skilled			
5 - Lower Clerical and Sales Personnel	11 (13.75%)	1 (1.25%)	6 (7.50%)
9 - Lower-skilled Workers	117 (15.88%)	3 (0.41%)	69 (9.36%)
10 - Lower-skilled Farm Workers	0 (0.00%)	0 (0.00%)	0 (0.00%)
Unskilled			
11 - Unskilled Workers	0 (0.00%)	0 (0.00%)	0 (0.00%)
12 - Unskilled Farm Workers	0 (0.00%)	0 (0.00%)	2 (13.33%)

Notes: The table shows the total number of patents extended to each British jurisdiction by HISCLASS group and their percentage relative to the total number of patents granted to each HISCLASS category. 'Scotland' includes the patents which were patented in England and extended only to Scotland. 'Ireland' covers patents extended solely to Ireland. 'Both' covers patents protected in all three patent jurisdictions.

patentees. Fifth, Unskilled persons did not seek extension presumably because of the costs, though two patents held by Unskilled Farm Workers were protected in all three regions, implying the existence of a financial backer.

The estimates show that extension costs did not discriminate much more heavily against lower social status and presumably poorer innovators, with the exception of the Unskilled. A possible explanation is that extension reflects the existence of a financier. Given the significant costs of inventing and patenting, inventors who lacked financial resources were forced to pursue financial partnerships where a financier would fund the inventor in expectation of a share of their invention's returns (MacLeod, 1998). Securing a patent right would also serve as a way to solidify the partnership through the acquisition of a tangible asset; financiers may have been more willing to back an inventor who sought patent protection. The prevalence of skilled patentees may reflect their attractiveness as an investment from a financier's perspective, as they could produce valuable inventions (Mokyr, 2009; Howes, 2017; Hanlon, 2021).[7] Therefore, I

[7]My assumption also suggests financiers could distinguish between skilled and unskilled inventors. It is likely they did so based on the signal from the inventor's occupation, as the occupation should provide a good indication of prospective skills. In this case, my assumption that skills are correlated with access to financial resources is reasonable; either the occupation listed on the patent is that of the financier (MacLeod, 1998), and if not, the occupation may be correlated with being able to attract a financier.

Table 5: Descriptors of additional variables

Variable	**Unit**	**Definition**
Topic-One	Categorical	Highest-scoring patent class
Topic-Two	Categorical	Second highest-scoring patent class
Number of Inventors	Count	Total count of named inventors per patent
Insiders	Discrete	1 if a patentee's occupation is related to their highest-scoring patent technology class, following Nuvolari and Tartari (2011); a value of 0 does not mean the inventor is an outsider
Foreign Communication	Discrete	1 if a patent was communicated from abroad
Gentleman	Discrete	1 if a patentee's occupation lists a status
Patent Agent	Discrete	1 if a patentee's occupation includes 'patent agent'
Patent Stock	Count	Cumulative number of patents held by an individual at the time of each new patent grant
Total Distance	km (000s)	Total distance a patentee would have to travel for patent protection, from the centroid of their listed county to the centroid of a city with a patent office (Dublin, Edinburgh, London)
Nationality	Categorical	Categorises patentees into English, Irish, Scottish, or Foreign groups based on their listed residence
Capital- or Labour-Saving	Categorical	Categorises patents into Capital-saving, Labour-saving, or not specified based on patent titles, following MacLeod (1998)
One-time Patentee	Discrete	1 if a patentee holds only one patent
Metropolitan	Discrete	1 if a patentee's listed town of residence has a population greater than 50,000 inhabitants, following Nuvolari and Tartari (2011)

Sources: Town sizes collected from Mitchell (1988). Patent topics are from Billington and Hanna (2020).

assume a patentee's skill correlates with their ability to finance their patents.

2.2 Explanatory Variables

Table 5 provides an overview of my additional explanatory variables and their definitions, which are used in my ensuing statistical analysis.

3 Supply-side factors and patenting behaviour

I investigate the link between patent value and supply-side characteristics, principally patentee occupations. My dependent variables , the WRI and BCI, are measures of a patent's value which I attempt to explain as a function of a patentee's skill and a set of control variables for other important patentee characteristics. I test occupations against the WRI measure using a negative binomial model, and against the BCI measure using OLS regression model. Equation 1 outlines my econometric strategy.

$$PatentValue_{it} = \alpha_{it} + \beta_1 Occupation_{it} + \beta Controls_{it} + \mu_{it} \quad (1)$$

The analysis here also builds on the work of Nuvolari and Tartari (2011) and Nuvolari et al. (2021), who examine several determinants of patent value. I extend their findings

Table 6: The determinants of patent value, 1700-1841

VARIABLE	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	WRI				BCI			
Occupations								
High-skilled	Baseline			Baseline	Baseline			Baseline
	Baseline			Baseline	Baseline			Baseline
Medium-skilled	-0.057***			-0.051***	-0.052***			-0.038***
	(0.016)			(0.016)	(0.012)			(0.012)
Low-skilled	-0.031			-0.031	-0.067***			-0.051***
	(0.030)			(0.030)	(0.016)			(0.015)
Unskilled	-0.078**			-0.064*	-0.096***			-0.069***
	(0.033)			(0.036)	(0.019)			(0.020)
Other Occupations								
Gentleman	-0.029*			-0.015	-0.046***			-0.036**
	(0.015)			(0.015)	(0.011)			(0.015)
Patent Agent	-0.023			-0.014	-0.012**			-0.006
	(0.019)			(0.021)	(0.005)			(0.010)
Patentee Characteristics								
One-time Patentee		-0.069***		-0.067***		-0.053***		-0.051***
		(0.012)		(0.012)		(0.011)		(0.011)
Capital-saving		-0.008		-0.010		0.015		0.014
		(0.017)		(0.017)		(0.012)		(0.012)
Labour-saving		-0.079***		-0.081***		-0.057***		-0.056***
		(0.028)		(0.028)		(0.019)		(0.020)
Number of Inventors		0.012		0.013		0.021**		0.021**
		(0.016)		(0.016)		(0.009)		(0.009)
Patent Stock		-0.007***		-0.008***		0.011***		0.011***
		(0.003)		(0.003)		(0.004)		(0.003)
Foreign Communication		-0.048***		-0.042***		0.001		0.003
		(0.013)		(0.013)		(0.005)		(0.004)
Metropolitan		-0.006		-0.006		-0.002		-0.002
		(0.012)		(0.013)		(0.010)		(0.010)
Insider		0.015		0.010		0.012		0.001
		(0.016)		(0.015)		(0.008)		(0.010)
Nationality								
Irish			-0.007	-0.023			-0.013	-0.007
			(0.051)	(0.054)			(0.012)	(0.014)
Scottish			0.103***	0.098***			0.080***	0.084***
			(0.034)	(0.034)			(0.029)	(0.031)
Foreign			-0.116**	-0.118**			-0.026	-0.017
			(0.055)	(0.057)			(0.023)	(0.025)
Constant	-0.069**	-0.115	-0.101***	-0.091	0.031	0.030	-0.008	0.060
	(0.028)	(0.104)	(0.025)	(0.103)	(0.020)	(0.093)	(0.016)	(0.099)
Time	Y	Y	Y	Y	Y	Y	Y	Y
Technology	Y	Y	Y	Y	Y	Y	Y	Y
Observations	8,221	8,221	8,221	8,221	8,220	8,220	8,220	8,220
R-squared	-	-	-	-	0.017	0.032	0.013	0.037
Pseudo R-Squared	0.00205	0.00242	0.00201	0.00282	-	-	-	-

Notes: The dependant variable in columns 1-4 is the WRI metric, using a negative binomial model. The dependant variable in columns 5-8 is the BCI metric, using OLS regression. The coefficients are interpreted as the difference in the logs of expected counts of the predictor variable. To translate this into a unit change, the coefficients need to be exponentiated. Time controls are taken from (Nuvolari and Tartari, 2011). I include a measure of inflation as a control variable, taken from Clark (2021). Clustered standard errors, by patentee's listed county, in parentheses ***p<0.01, **p<0.05, *p<0.1.

Sources: Author's calculations using data from Woodcroft (1854), Mitchell (1988), Nuvolari and Tartari (2011), Bottomley (2014a), and Nuvolari et al. (2021)

by including occupational measures, as well as additional measures capturing potential access to financial resources and the nature of invention. The authors also apply their own classification schema, while I adopt the Billington and Hanna (2020) schema.[8]

[8]See Appendix C for a discussion of the technology classes, and an analysis of which technologies were associated with particular skill-groups.

Table 6 reports my results. Occupations are categorised into one of four HISCLASS skill groups. Here, the baseline category are 'High-skilled' patentees. I report the results for occupations, patent characteristics, and nationality separately and then together to observe whether the results change with the inclusion of different variables.[9] My discussion focuses primarily on the results of my supply-side factors.

My key finding is that supply-side factors are correlated with a patent's value. High-skilled patentees held patents which received, on average, 6-8 per cent more references and had BCI scores 4-7 per cent higher compared to their less-skilled counterparts.[10] Patents held by the Low-skilled group were less valuable compared to High-skilled occupations, though the result is only statistically significant for the BCI measure.

'Other Occupations' indicate that Gentlemen patentees were patenting less valuable inventions compared to patentees listing an occupation, though the results are not statistically significant once controls are introduced for the WRI measure. Patent Agents do not seem to have influenced a patent's value, suggesting they were helpful in seeking patent protection rather than enhancing the value of any invention they patented.

Several patentee characteristics are also correlated with patent value. One-time Patentees protected less valuable inventions compared with more intensive users, while Patent Stock suggests intensive users opted to protect their best inventions first. Intensive use of the patent system is also correlated with a patentee's skill and social status. This may also explain the occupational results, to an extent: Low-skilled patentees were likely opting to patent only their most valuable invention, while High-skilled patentees protected their most valuable inventions alongside other less valuable ones. However, the BCI result instead reports a positive correlation, which likely captures the prolific patenting activity of great inventors.

The results indicate that the value of patented inventions is correlated with supply-side

[9] Appendix D reports the complete set of results, including the results for my technology groups.

[10] Hanlon (2021) recently argues that engineers were key drivers of valuable innovations which entered the patent system. Consequently, in Appendix E I test how important engineers were as drivers of valuable patenting by removing them from my analysis of patent value and patentee skills. Once excluded, I find similar correlations, though the results are only statistically significant when using the BCI metric.

factors. Patent value is also correlated with patent extension, as patentees recognise their inventions are capable of exploiting market opportunities in Britain (Bottomley, 2014a). But, the decision to patent widely may also be correlated with who is patenting; since skilled inventors produce more valuable inventions, the inventor's skill and likely access to financial resources may be an alternative explanation for their behaviour.

I test whether patentee occupations help explain patent extension. Here, I augment Bottomley to explain patent extension using a probit regression model, as described in equation 2. My approach contrasts Bottomley's, who applies a Mann-Whitney non-parametric test to establish a correlation between patent value and patent extension; I am able to discuss whether patent value or patentee characteristics were more important when deciding to extend protection.

My dependent variable is dichotomous, taking a value of zero if the patent was protected solely in England and a value of 1 if it was extended. I examine the propensity to extend patent protection to Scotland, to Ireland, then both Scotland and Ireland together (Both). All standard errors are clustered by a patentee's listed residence at the county level.

$$PatentExtension_{it} = \alpha_{it} + \beta_1 PatentValue_{it} + \beta_2 Occupation_{it} + \beta Controls_{it} + \mu_{it} \quad (2)$$

Table 7 reports my key results.[11] Here, I only report results using the WRI measure; the BCI measure produces similar results. Patent value is correlated with patent extension in each specification, with the exception of column 6, which broadly supports Bottomley's findings. Bottomley's conclusion that market opportunities were a relevant factor to extension is supported, though the results indicate value is not the sole reason.

Patentee occupations also report some correlation with extension, but the findings are not statistically significant. Medium-skilled patentees are negatively correlated with patent extension, while Low-skilled report both positive and negative signs depending on which jurisdiction they extended protection to. Unskilled patentees were much less likely to extend protection to one jurisdiction, but they report a positive correlation for

[11] The complete results, including my technology controls, are contained in Appendix D.

Table 7: The determinants of patent extension, 1700-1841

VARIABLE	(1)	(2)	(3)	(4)	(5)	(6)
	Scotland		Ireland		Both	
Patent Value	0.038***	0.034***	0.010***	0.007***	0.031***	0.010
	(0.009)	(0.007)	(0.001)	(0.001)	(0.005)	(0.018)
Occupations						
High-skilled		Baseline		Baseline		Baseline
		Baseline		Baseline		Baseline
Medium-skilled		-0.024		-0.002		-0.004
		(0.014)		(0.002)		(0.008)
Low-skilled		0.016		-0.009*		0.002
		(0.016)		(0.005)		(0.006)
Unskilled		-0.076				0.006
		(0.057)				(0.017)
Other Occupations						
Gentleman		0.005		0.003*		0.008
		(0.011)		(0.002)		(0.015)
Patent Agent		-0.041***		0.005**		-0.014
		(0.008)		(0.002)		(0.026)
Patentee Characteristics						
One-time Patentee		-0.023***		-0.006**		-0.014**
		(0.007)		(0.003)		(0.006)
Capital-saving		-0.027***		-0.012***		0.000
		(0.010)		(0.004)		(0.004)
Labour-saving		0.013		0.004		0.004
		(0.030)		(0.005)		(0.011)
Patent Stock		-0.002		0.000		-0.001
		(0.002)		(0.000)		(0.002)
Insider		0.004		-0.000		-0.002
		(0.010)		(0.002)		(0.003)
Number of Inventors		0.017		0.001		0.004
		(0.011)		(0.003)		(0.009)
Foreign Communication		0.039***		0.005*		0.010
		(0.011)		(0.003)		(0.018)
Metropolitan		0.005		0.005		0.004
		(0.013)		(0.003)		(0.008)
Nationality						
Irish		0.096**		0.049***		0.035
		(0.044)		(0.008)		(0.065)
Scottish		0.242***		0.011		0.039
		(0.040)		(0.016)		(0.075)

Continued on next page

Table 7 – continued from previous page

VARIABLE	(1)	(2)	(3)	(4)	(5)	(6)
Foreign		0.176***				-0.017
		(0.052)				(0.048)
Distance to Patent Office						
Total Distance (Scotland)		-0.610***		0.066		-0.113
		(0.224)		(0.081)		(0.282)
Total Distance Squared (Scotland)		0.233*		-0.061		0.076
		(0.125)		(0.061)		(0.195)
Total Distance (Ireland)		0.401**		-0.224*		0.234
		(0.156)		(0.115)		(0.416)
Total Distance Squared (Ireland)		-0.012		0.177*		-0.175
		(0.072)		(0.101)		(0.317)
Total Distance (All)		0.062		-0.388**		-0.028
		(0.145)		(0.172)		(0.138)
Total Distance Squared (All)		-0.098*		0.194**		0.015
		(0.057)		(0.092)		(0.070)
Time	N	Y	N	Y	N	Y
Technology	N	Y	N	Y	N	Y
Observations	7,386	7,386	5,563	5,563	8,084	8,084
Pseudo R-Squared	0.0599	0.174	0.0319	0.166	0.0328	0.121

Notes: Probit results for extending patent protection either to Scotland, Ireland, or both. Columns 1-4 show results for patents extended either only to Scotland or Ireland. Columns 5-6 examine patents extended to Ireland and Scotland. Coefficients are interpreted as marginal effects at the means. My technology controls include both Topic-One and Topic-Two. Time controls are taken from (Nuvolari and Tartari, 2011). I include a measure of inflation as a control variable, taken from Clark (2021). I include a dummy variable for 1775-1827, and one for 1828-1841, following the analysis in Bottomley (2014a). Clustered standard errors, by patentee's listed county, in parentheses ***p<0.01, **p<0.05, *p<0.1.

Sources: Author's calculations using data from Woodcroft (1854), Mitchell (1988), Nuvolari and Tartari (2011), and Bottomley (2014a).

extension to all regions.

'Other Occupations' report a correlation between Gentleman patentees and patent extension; patentees listing status occupations were much more likely to patent in all jurisdictions, though they were also patenting less valuable inventions. Gentleman patentees were then arguably 'vanity patenting' to enhance their prestige rather than to protect valuable innovations (MacLeod and Nuvolari, 2006). Patent Agents were less likely to obtain patent extension to Scotland, though they were marginally more likely to patent inventions extended to Ireland.

Patentee characteristics report additional correlations. One-time Patentees were less likely to extend patent protection, but were also less likely to patent valuable inventions. Either One-time Patentees were less willing to extend protection, or they could not afford the additional fees. Given their invention's were typically of a lower economic value, either the patentee or their financial backer were unwilling to expend the necessary funds for widespread protection. .

4 Conclusion

Sean Bottomley, in this journal, identifies a link between a patent's value and how many jurisdictions it was protected in, arguing that patentees responded to market opportunities. I augment and extend Bottomley's findings in three ways. First, I find the supply of knowledge, as captured by occupation, mattered for a patent's value. Second, I find that patent extension was driven by the invention's value rather than the skills of the inventor, which may suggest the decision to patent is based on the value of the invention. Third, I observe the over-representation of skilled inventors in the patent system, who may have patented more often because they held a greater number of valuable, patentable inventions.

My results highlight the relationship between human capital and technical change. Technical change during the Industrial Revolution was skill-demanding, resulting in an increasing share of skilled persons in Britain's workforce (de Pleijt et al., 2020). These skilled persons, who comprise the upper tail of human capital (Mokyr, 2005; Zeev et al., 2017) were also producing and patenting valuable inventions, indicating the existence of a virtuous circle. The upper tail were intense users of the patent system and frequently extended their protection, which suggests they also responded to market opportunities.

Occupations, however, are not sufficient to explain a patentee's decision to extend their protection. Instead, a patent's value remains an important determinant; regardless of their inventor's economic background, a valuable patent was more likely to be protected widely in Britain. Britain's patent system, while not as open-access as the United States' (Khan, 2005), may have been more open than it is given credit for. Lower status inventors did secure patent rights and also extended their patent protection despite the significant expense. This observation may indicate the presence of a financier. From a financier's perspective, a patent right for a valuable invention may have been a worthwhile investment, as the patent can be used to try and exclude imitators from appropriating any potential returns. Access to the patent system may then have depended on an invention's value, insofar as value attracts financial support.

In conclusion, patenting behaviour can be explained through a combination of demand-side and supply-side factors. The case of James Watt and his famous separate condenser exemplifies this relationship. Watt's motivation for inventing was the prospect of financial returns (Dutton, 1984). He was also an engineer (Woodcroft, 1854), and his separate condenser is one of the most famous inventions of the Industrial Revolution. But, Watt required financial assistance to develop his invention and secure his patent, which he originally received from John Roebuck in exchange for a share in the invention (Bottomley, 2014b). For Roebuck, holding a share of Watt's invention was likely a sufficient return; Roebuck probably invested because he thought the invention was valuable. The evidence presented in this paper may suggest that Watt's experience was not entirely unique.

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