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Powertrain Electrification and the Global Race for Battery Industry Dominance: A Technometric Analysis

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Abstract

This paper presents the results of a technometric analysis of battery patents. The results confirm the view that Japan and Korea lead the battery technology sector not only in manufacturing but also in R&D activity, which is measured using patent stocks as a proxy. We also found that the battery patent portfolios of these countries are younger than those of other countries, and that Japan and Korea are also more "specialized" in battery technology, i.e. they have in the past allocated a higher share of their total R&D efforts to batteries than other countries. A possible implication of these results is that Asia's competitive advantage in battery technology is likely to *increase* over time relative to North America and Europe. A further implication is that Asian countries led by Japan and Korea stand to benefit the most from the trend toward powertrain electrification in the global automotive industry.

Keywords: Battery, BEV (battery electric vehicle), electric drive, EV (electric vehicle), EU (European Union), HEV (hybrid electric vehicle), lithium battery, policy, subsidy, United States of America

1 Introduction

It is well known that Japanese, Korean and Chinese firms dominate the world market for lithium batteries, which are currently used mainly in consumer electronics applications (e.g. see [1]). Several Japanese firms, including Sony and Panasonic/Sanyo, have also played a critical role in the development of these battery technologies [2]. This might suggest that Asian firms are entering the emerging electric vehicle (EV) battery industry with a natural advantage, given that most if not all of the current EV manufacturers use or plan to use lithium-ion type batteries. Moreover, all the major hybrid and EV models currently available utilize technology sourced from Japanese or Korean based suppliers.

This could have significant economic and political consequences if the 'electrification' of the automotive industry were to continue to progress. After all, the hybrid and EV market provides much larger commercial and employment opportunities than the consumer electronics industry. Not surprisingly, a number of North American and European policymakers and industry leaders have already recognized this risk [3] [4], [5].

Some actions have been taken; the US Department of Energy and other public agencies have dramatically increased funding and other incentives for battery technology R&D and even manufacturing. R&D efforts to develop an early position in 'post-lithium' batteries might be the most promising in this regard. As noted by [6],

"(...) the battery, among the most humble and unsexy of inventions, might just be the most important technological battleground of the next two decades. The discovery of the

next key breakthroughs in the field could mean not just a fortune for a handful of companies, but the remaking of whole economies -- and the rebalancing of geopolitical power that typically accompanies such shifts."

While it is too soon to tell if current R&D efforts conducted in the US, Germany and other countries will have any impact on the balance of trade in hybrid and EV batteries, it can be useful to consider just how dominant the current Asian position is. Indeed, it would be naive to think that companies such as Sanyo/Panasonic, Sony, LG Chem and Samsung will be unable to adapt to changing technological and market dynamics in the global battery industry. For example, they are likely to be able to apply their lithium (and nickel-metal hydride) battery manufacturing and supply chain management expertise to future battery chemistries. Knowledge of manufacturing processes is especially important in the battery industry, and can only be developed over long periods of time through trial and error [7], [8]. As noted by [9], high-volume manufacturing capacity and experience are essential to meet the cost and quality challenges of automotive applications – "maybe more than cell chemistry". We conclude from this that current expertise in battery technology will likely continue to be relevant for some time, regardless of whether the automotive industry transitions to 'post-lithium' batteries or not.

2 Methods

In this paper, we use technometric methods to analyze patent data from the United States Patent and Trademark Office, seeking to rank and assess countries in terms of the volume, age and quality of their battery patent portfolios. We also measure and compare the amount of R&D allocated in each country to batteries relative to total R&D effort. While such an analysis can only give a partial view of the relative strengths and weaknesses of each country in battery technology, we believe it provides significant insights into the emerging battleground for world battery technology and industry dominance.

Technometrics is essentially the application of bibliometrics to measure innovation based on patents [10]. Patent statistics were chosen as they provide objective and reproducible data for tracing the evolution of specific technological fields [11], [12], [13]. Alternative methods, such as scanning R&D activity and strategy from product demonstrations, new product announcements and presentations at various conferences, tend to be anecdotal and potentially misleading. Case studies based on 'insider' interviews can reveal considerable insight into specific firm activity, but are necessarily limited in scale and scope and not easily comparable with other studies. In contrast, patents are publicly available records of innovative activity, containing a range of useful information such as the identity and corporate affiliation of the inventor, the date and location of the invention, and the 'prior art' on which the invention is based (which must be cited in the patent). Crucially, the patenting process requires inventors to describe important aspects of their invention in the patent. This makes it possible to identify and capture large numbers of related patents through Boolean search queries. While not without weaknesses, patent statistics thus provide a relatively objective and standardized proxy for R&D activity, which can then be used to trace the evolution of a technological field, identify key actors and national trends, and so on.

For this study, we designed a complex Boolean search query to capture and retrieve patents related to the area of advanced power source technology, including batteries and fuel cells. Our query generated a set of 30,000 patents, which provided a wealth of data on industry dynamics in these technological fields.

3 Results

Here we focus on the results concerning batteries. As a whole, the data confirms that Japan and Korea lead the battery technology sector not only in manufacturing but also patent stocks (see Figure 1). Moreover, we found that the battery patent portfolios of these countries are relatively "young" compared to those of other countries and regions, i.e. a relatively high share of Japan and Korea battery patents still have over 10-15 years of lifetime.[i] Japan and Korea are also more "specialized" in battery technology, i.e. they allocate a higher share of their total R&D efforts to batteries than other countries.[ii] The combination of young portfolios and relatively high levels of specialization puts these countries in an ideal position, in the "golden quadrant" of Figure 1.

Additionally, complementary data not shown here shows that while all car manufacturers are dependent on the (Asian) consumer electronics industry for battery technology, Japanese car

manufacturers have tended to invest more in battery technology R&D than their peers in other countries [14].

4 Discussion

The main implication of these results is that Asia's advantage in battery technology is likely to *increase* over time relative to the North America and Europe. Unless the rate of battery R&D increases in the latter regions, the combination of aging (and therefore expiring) patents and lower levels of R&D specialization could, in theory at least, lead to a further deterioration of their positions in battery technology and hence in the emerging hybrid and EV industry.

These results are of course subject to a number of caveats. Like all R&D indicators, patents have a number of shortcomings. For example, not all economic or technologically significant innovations are patented. Patenting intensity varies across individuals, organizations, industries and countries depending on corporate strategy, resources for patenting (a relatively expensive process) and legal and competitive environments [15], [12]. Also, there is evidence that small firms and manufacturing inventions are underrepresented in patent counts [16].

Nevertheless, we believe our results are significant as they are consistent with a number of readily observable trends such as manufacturing capacity investments and joint venture developments. Indeed, our results will come as no surprise to industry insiders.

What the data clearly does not say is whether more recent R&D efforts have managed to significantly alter the position of the US and other major countries, since patent stocks reflect R&D efforts of at least several years ago. Recent initiatives to develop new battery chemistries could, if successful, lead to breakthroughs in battery technology, possibly involving material combinations that are far removed from today's dominant lithium-ion design. This might make current rankings and positioning irrelevant. However, as already noted, it is likely that current leaders will be able to apply their manufacturing and supply chain management expertise to future battery chemistries. Clearly, some countries are entering this global race for domination of the advanced battery industry with significant advantages.

Further studies using technometrics to monitor and assess developments in battery technology are therefore suggested.

Notes

[i] For example, the US Portfolio Age Index was calculated as TANH(LN((Sum of US battery patents expiring in 2018-2027/all US battery patents)/(Sum of world battery patents expiring in 2018-2027/all world battery patents))

[ii] For example, the US Specialization Index was calculated as follows: TANH(LN((US battery patents/all US patents)/(world battery patents/all world patents))

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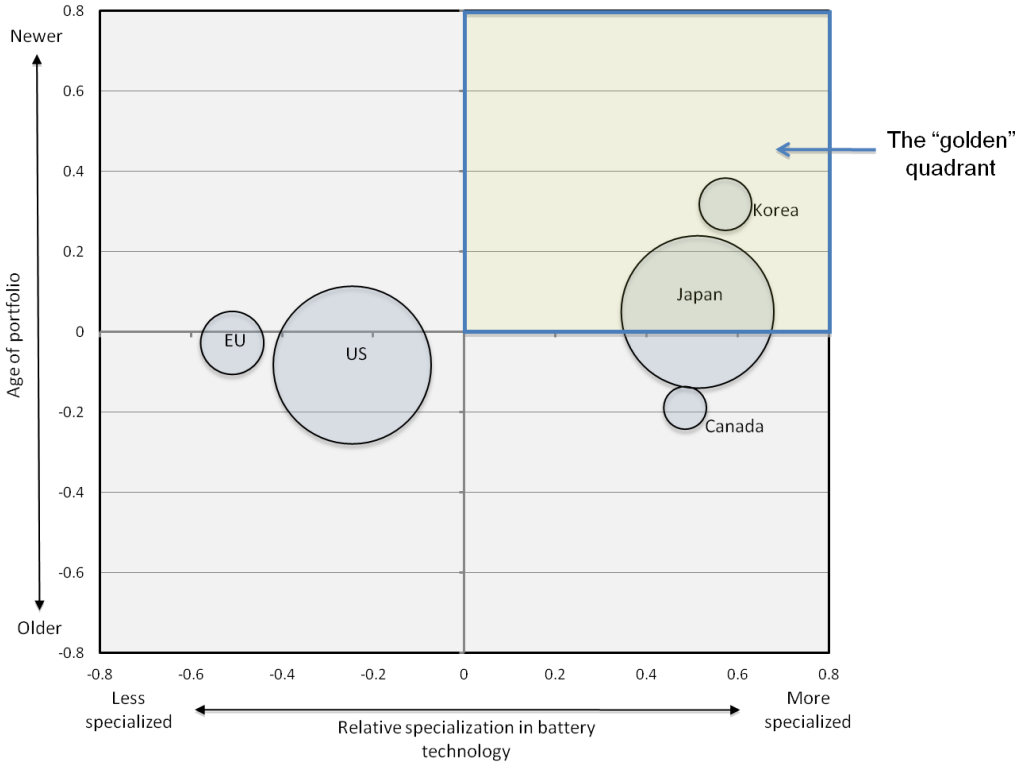
Figure 1. National battery patent portfolios: An international comparison
Data source: United States Patent and Trademark Office (USPTO), patents up to 2008



Note: The size of each bubble is determined by the relative number of total active patents.