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Analysis of The Impact of Government Subsidies on Competitiveness in the Automotive Sector

Neo-Schumpeterian trade theory implies that the absolute advantages of countries in terms of costs and technology are the key determinants in the constant adjustment process of trade between countries and heavily determine the competitiveness of firms in industry. The neoclassical theory, on the other hand, relies upon the theory of a convergence of levels of productivity between countries, a theory seen to be lacking empirical basis and not sustained by the case of the automotive industry. The underlying quality and differentiation of German and Japanese automobiles due to their historical technological endowment underpin the competitiveness of their respective countries as per Paul Krugman, which then stimulates the competitiveness of those firms through reputation, which enables vertical and horizontal differentiation processes. The constant adjustment process is confirmed by the automotive industry, rather than the neoclassical convergence theory due to the rise of Chinese firms in the automotive industry brought forth by technological mastery of electric vehicle production. However, the technological mastery of electric vehicle-specific technologies can be partly explained not only by an exogenous adjustment process, but by strong governmental intervention in the form of subsidies, which facilitated the entry of Chinese firms on the market. The automotive sector is of strong social and economic significance. Studies including indirect effects amount the contribution of the automotive sector to 7% of GDP in the European union. Furthermore, the strategic implications in terms of dependence on other actors render the industry all the more important. While governments have reverted to various forms of protectionism, particularly educational protectionism developed by John Meynard Keynes and strategic protectionism first identified by Friedrich List. While it can be argued that protectionism, due to the rationality of reciprocal tariffs, can be suboptimal for the expansion of domestic firms, the effects are primarily a decrease in consumer choice and bargaining power as per the neoclassical theory of pure and perfect competition.

Governments have seen pressure to subsidise markets, particularly the automotive sector due to its strategic and economic significance, as a result of exogenous shocks and increased competitiveness of Chinese electric vehicles, partly itself due to subsidies. The use of subsidies in certain markets is justified by economists such as Mariana Mazzucato and Joseph Stiglitz, if considered as being of social significance due to the conservation of jobs and an effort towards sustainability. However, the benefits of subsidies are widely contested, particularly by the likes of Friedrich August Von Hayek and Milton Friedman, who point at the creation of market inefficiencies and the misallocation of resources.

Comprehensive studies on the impact of subsidies, such as that of Becker (2015), have proved the increase in R&D expenditure and private funding stimulated by subsidies, the increase in R&D collaboration between entities, but found an unequal impact of subsidies based on the company's size due to an increased project efficacy. Furthermore, Broekel et al. (2017) emphasise the importance of the medium of subsidisation, and discrepancies in the benefits received from subsidies.

Furthermore, recent studies such as that conducted by the Stanford Institute for Economic Policy Research quantified the impact of subsidies, particularly tax incentives and purchase subsidies in influencing consumer choice and consumption, notably towards electric and alternative fuel vehicles.

However, these studies do not strive to find a relation between overall subsidy spending and the competitiveness of the automotive industry in the studied countries. This study would allow the

evaluation of the overall effectiveness of subsidies and the underlying effectiveness of the allocation of resources. Furthermore, it would allow the determination of whether subsidies do truly cause a large increase in competitiveness, with genuine justification for protectionism. This research was conducted with the goal of solely utilising reliable data and using relatively basic mathematical tools such as linear regression models and Granger causality tests, partly induced by scarcity of reliable data.

Linear regression model: subsidies and revenue generation of the automotive industry
Firstly, a linear regression model that will aim to establish the existence or nonexistence of a relationship between subsidies and the revenue generation of the automotive sector of that country will be studied. We will establish the dependent variable(X) as the revenue generated by the automotive sector in a given country. Secondly, we will establish the independent variable(Y) as issued subsidies.

We will establish the null hypothesis $H_0: \beta_1 = 0$, which implies no correlation between governmental subsidies and the generation of revenue of the automotive industry of the country. The alternative hypothesis $H_1: \beta_1 \neq 0$ implies there is a correlation between subsidies and the country's revenue generated by the automotive industry. The previously argued classification of the automotive industry as benefitting from subsidies, because of capital intensiveness of the industry due to high competition as per Augustin Cournot(1838)'s vision of oligopolistic competition implies the expected result to be the confirmation of H_1.

$$Y_{i,t} = \beta_0 + \beta_1 X_{i,t} + \beta_2 Z_{i,t} + \epsilon_{i,t}$$
Where,
$Y_{i,t}$ corresponds to the revenue generated by the automotive sector of country i in year t
$X_{i,t}$ corresponds to the estimated subsidies for country i in year t.
$Z_{i,t}$ is the vector of control variables (firm size, market share, etc.).
β_0 is the intercept.
β_1 is the coefficient for subsidies, measuring its impact on the revenue generated by i country's automotive sector.
$\epsilon_{i,t}$ is the error term capturing unobserved influences.

The following data can be retrieved from USA data from 2008-2023:

Same year subsidies prediction of revenue in the USA	slope	intercept
coefficient for slope, for intercept	-0.08716277648	54.80894015
Standard error for slope, for intercept	0.02705593927	14.52841903
Coefficient for determination, standard error	0.4257247756	9.66416033
F stat w/ degrees of freedom	10.37855475	14
Regression SS, residual SS	969.3154465	1307.543928

A relatively significant R-squared value of approximately 42.57 can be observed. The R-squared value determines the extent to which the variance in the dependent variable is explained by the independent variable. Ranging from 0 to 1, with a R-squared value of 0 entailing no explanatory power and a value of 1 meaning the independent variable fully explains the variance in the dependent variable fully. Such a value is decent due to the multiplicity of factors that explain automotive sector revenue generation, particularly the impact of the overall economic climate of major markets.

$$t = \frac{\beta}{SE(\beta)} = \frac{-0.08716277648}{0.02705593927} = -3.221$$

With the calculation of the t-statistic, where β is the coefficient for the slope and $SE(\beta)$ is the standard error for the slope, we could establish a negative correlation between subsidies and revenue generation in the automotive industry. With no additional context, the data would say that more the US government subsidies, the less revenue is generated by the industry. However, the fact a government deems subsidies necessary points at economic hardship for the industry. Indeed, where the US government has subsidised the most in our dataset, 2008 and 2009, through the troubled asset relief program, was when the economic situation was the most dire for car manufacturers due to weak demand. This does not prove anything significant in the context of the evaluation of the efficacy of subsidies in this particular context.

The calculation of the p-value using a cumulative distribution function will allow for the proof of the robustness of the relation between subsidies as an explanation of revenue. The p-value of approximately 0.0062 renders the model robust. However, it does not illustrate nor deny the desired information. It demonstrates that subsidies do not affect the revenue of automakers in the same year.

This lack of desired information now justifies the study of the impact of subsidies on the revenue of the car manufacturing industry the year after. However, incorporating a time lag with: $Y_t + k = f(X_t, Z_t)$

does not address the problem of the model not identifying the desired relation, but rather solely confirms the reactive nature of subsidies and may be showing that low industry revenue induces subsidies with a negative t-statistic and coefficient for slope.

Linear regression model: subsidies and trade balance of automotive products

Secondly, a linear regression model that will aim to establish the existence or nonexistence of a relationship between subsidies and the trade balance in terms of automotive products will be explored. We will establish the dependent variable(X) as the trade balance of automotive products. Secondly, we will establish the independent variable(Y) as issued subsidies.

We will establish the null hypothesis $H_0: \beta_1 = 0$, which implies no correlation between governmental subsidies and competitiveness in trade balance of the automotive industry of the USA. The alternative hypothesis $H_1: \beta_1 \neq 0$ implies there is a correlation between subsidies and the country's trade balance of automotive products. Once again, the previously argued classification of the automotive industry as benefitting from subsidies, because of capital intensiveness of the industry due to high competition as per Augustin Cournot(1838)'s vision of oligopolistic competition implies the expected result to be the confirmation of H_1.

$$Y_{i,t} = \beta_0 + \beta_1 X_{i,t} + \beta_2 Z_{i,t} + \epsilon_{i,t}$$

Where,

$Y_{i,t}$ corresponds to the trade balance of automotive products of country i in year t

$X_{i,t}$ corresponds to the estimated subsidies for country i in year t.

$Z_{i,t}$ is the vector of control variables (firm size, market share, etc.).

β_0 is the intercept.

β_1 is the coefficient for subsidies, measuring its impact on i country's automotive products export to import ratio.

$\epsilon_{i,t}$ is the error term capturing unobserved influences.

The following data can be retrieved for the USA for the period 2008-2023:

	slope	intercept
Same year prediction of trade balance of USA in terms of automotive products		
coefficient for slope, for intercept	0.4185325777	57.17987072
Standard error for slope, for intercept	0.1484080257	17.3934032
Coefficient for determination, standard error	0.3622807469	10.18401079
F stat w/ degrees of freedom	7.953234015	14
Regression SS, residual SS	824.8623149	1451.99706

While the desired outcome of a positive t-statistic=0.4185 value is shown, it demonstrates the same reactive nature of subsidies due to the negative values of the American trade balance of automotive products and therefore is incapable of determining the sought-after relation.

Granger-causality test
A Granger-causality test will be used to determine whether it is correct to state that subsidies lead to increased competitiveness of the domestic automotive sector through an increase in revenue, using US american data. A Granger causality test consists in the following: there are 2 time series, X_t representing estimated revenue of the automotive sector of the USA and Y_t representing subsidies paid by the US government to the automotive sector. The goal is to see if the past values of X provide information on the future value of Y beyond what is already said by the previous values of Y.

Restricted model:

$$Y_t = \alpha_0 + \sum_{i=1}^{p} \beta_i Y_{t-i} + \epsilon_t$$

With p being the number of lags and ϵ_t the error. Here, Y_t is modeled according to its past values.

Unrestricted model:

$$Y_t = \alpha_0 + \sum_{i=1}^{p} \beta_i Y_{t-i} + \epsilon_t + \sum_{i=1}^{p} \gamma_i X_{t-i} + \epsilon_t$$

In the unrestricted model, the past values of X_t are added to measure their predictive ability of the future values of Y_t.

$$F = \frac{(RSS_R - RSS_U)/p}{RSS_U/(n-k)}$$

With:

RSS_R corresponding to the residual sum of squares for the restricted model,

RSS_U corresponding to the residual sum of squares for the unrestricted model,

n being the total number of observations,

k the number of parameters in the unrestricted model

We find the following p-values associated with the F-statistics:

Lag 1: $p=0.389$
Lag 2: $p=0.059$
Lag 3: $p=0.796$
Lag 4: $p=0.440$

The sole statistically relevant relation is demonstrated by lag 2. By defining the robustness of a relation with $p \leq \alpha = 0.05$, we can see lag 2 has a moderate predictive relationship. It may however, show that the relative short-term impact of subsidies is more significant than the relatively long-term impact. Were the predictive relationship more significant for lag 2, it would allow the establishment of the maximum beneficial impact of subsidies being seen after 2 years, and a weaker positive impact 2 years onwards. The cause for this can be justified by the Keynesian vision of subsidies as primarily acting on demand, which would then demonstrate the longer reaction time of demand for automotive products. This would therefore support the vision of the demand for automotive products as being relatively elastic.

Tailoring subsidies for maximal impact on revenue would see the predictive relationship increase. It was recently highlighted that the 7,500 US dollar federal tax credit for electric vehicles in the USA predominantly benefited Americans that would have purchased electric vehicles regardless of the tax credit. Such an initiative, among other suboptimal forms of subsidies reduce the causality relation, and can be perceived as being a misallocation of resources.

Comparison of automotive trade balance depending on subsidy spending

Data comparing areas where governments subsidise the automotive industry less and heavily interventionist governments will be used to quantify the extent to which subsidies truly aid the competitiveness of the automotive industry of countries. This will show, to a certain extent, industry reactions to exogenous and endogenous shocks with no, or reduced, governmental intervention. This will in no case be complete proof of the efficacy of subsidies due to differences in the extent to which countries suffer from exogenous forces, and differences in the exogenous forces they are submitted to at all but will be useful in proving how subsidies are useful in the mitigation of economic shocks. When comparing the USA with the EU, there are great similarities in trends relating to the ability of the sector to come back from shocks. This ability is not present when analysing New Zealand, which subsidises the automotive sector much less than the USA or the EU. The same can be observed with Canada. Both countries have seen a consecutive period of decline in its trade balance of automotive products in the years 2010-2016, which for the EU was a period of strengthening of the trade balance. The data suggests

that the automotive industry benefits from subsidies because they smooth shocks and allow for a more rapid transition out of losses. Subsidies can therefore be considered rational and necessary to smooth the impact of crises.

**Game theory analysis of the rationality of subsidies**
Multiple game theory frameworks work in the establishment of subsidies as rational. Subsidies naturally constitute a Nash equilibrium and a there is a first-mover advantage associated with them:

Firstly, subsidising the automotive industry constitutes a Nash equilibrium, where the defensive allocation of resources underscores the strategic nature of subsidies, particularly in protecting industries deemed crucial for national interest. The equilibrium persists despite its inefficiency at a global level, as no single nation can afford to unilaterally eliminate subsidies without risking industrial and technological decline. The trade-off is particularly pronounced in industries with high capital intensity and innovation cycles, where the marginal benefits of staying competitive outweigh the fiscal inefficiencies of subsidies.

The first-mover advantage in subsidies further amplifies competitive disparities, with early entrants securing long-term dominance in emerging sectors such as electric vehicles. The Chinese automotive sector exemplifies this, as initial investments created a market environment that favored domestic manufacturers, fostered technological advancements, and shaped global supply chains. Late entrants, by contrast, face structural disadvantages, often being forced into suboptimal subsidy regimes to merely retain competitiveness. These reactions highlight the strategic misalignment often found in lagging economies, where subsidies serve to mitigate losses rather than generate first-order competitive gains.

While an equilibrium ensures that subsidies remain ubiquitous, the first-mover advantage redistributes the gains from such strategies unevenly, entrenching early leaders while perpetuating the reactive policies of lagging nations. This creates a cyclical dependence on protectionism, as late movers are compelled to maintain inefficient subsidies, effectively locking them into a state of industrial dependency. The broader implication is a persistent global subsidy race, driven by both competitive necessity and the strategic imperatives of individual nations. This dual dynamic emphasizes the inherently strategic, rather than purely economic, nature of subsidy policies in highly competitive industries.

Competition is more innovation-stimulating than subsidies themselves

Patents filed by US automotive sector
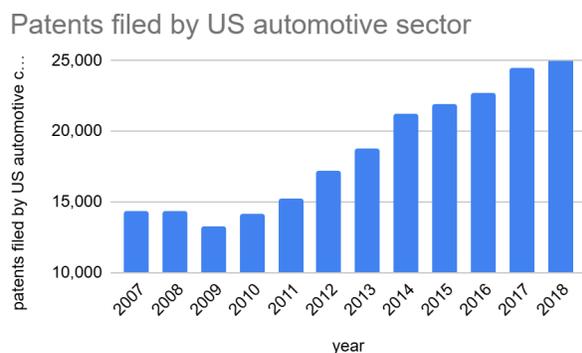
Overall historical trends have demonstrated that innovation is the product of competitive pressure and the overall economic climate, notably due to the cost and availability of capital. An increase in

competitiveness has the effect of facilitating the access to capital to invest in R&D, notably subsidies, which stimulate private investment through a buy-in effect. However, it also fundamentally shifts the need to innovate and the allocation of preexistent liquidity towards R&D. This is supported by a Schumpeterian vision of the impact of competition on technological progress, and proved by Aghion et al. (2015) by the finding of an inverted U-shaped relationship between competition and innovation. Furthermore, the overall emphasis put on innovation by firms is also shifted by the overall economic climate and investor expectations. Moderate competition allows for an increased allocation of funds towards R&D while ensuring the availability of these funds excluding subsidies and allows for the moderate satisfaction of investor expectations in terms of returns through dividends, without limiting the flow of capital nor the need for innovation. The policy implication derived from this would be the putting in place of only moderately protectionist policies, both in terms of tariffs to allow for competitive pressure to incite innovation without limiting the availability of funds, and in terms of subsidies, to allow for solely a pragmatic application of these through uses that directly affect core indicators of performance such as a global increase in revenue of the domestic automotive sector and the trade balance of automotive products.

Failures of competition render subsidies useful

There are, however, failures of competition itself which render the use of subsidies useful. The first is the financial risk associated with the investment into R&D to remain competitive, which can be avoided if the government is too protective of its industry and reduces the competition through tariffs. Subsidies enable the breakthrough of high potential technologies and reduce the financial risk associated with investment.
The reduction of financial risk does not solely happen in the point of view of the company however. Subsidies also allow the simultaneous investment into R&D and the satisfaction of the company's shareholders through dividends, and therefore reduces the binary choice companies are faced with: maximising the short-term satisfaction of investors or the long-term satisfaction of investors through the potential development of monetizable new technologies at the expense of the maximisation of their short-term satisfaction. Furthermore, strategic protectionism comes at the expense of the pressure to innovate and the long-term competitiveness of domestic firms due to strategic protectionism, contrarily to educational protectionism, de facto not being considered temporary.

Limitations and future studies

Several difficulties can be encountered when aggregating government incentives for consumption, production. The first was the difficulty recognising the time the lump sums recorded in program and federal reports were spent and issued. There are therefore discrepancies between the assumptions on the way spending was conducted and the time funds were truly spent. This therefore partly minimises the relation between government spending in the form of subsidies if H_1 were to be accepted as true.

Furthermore, the lump sums recognised in project reports aggregate spending during several years. This therefore increases the difficulty of recognising spending by year. For instance, the American troubled asset relief program was not spent equally through 2008 and 2009, yet through incapability to measure their spending per year, it will be assumed that the estimated 80 billion US dollars was spent equally through 2008 and 2009. For the USA, data on the revenue generated by the automotive industry by year was compiled from an aggregation of data from Statista, IBIS world and GoodCarBadCar. This entails varying reliability of the data points. Data on the USA's share in global vehicle production from 2008 to 2023 was provided by a singular reliable source, increasing the reliability of the established relations and

conclusions, meaning data comes from a range of reliable to moderately reliable sources. Access to data of other countries would enable more detailed and conclusive research.

To further understand the explored dynamic, it would be beneficial to investigate whether subsidies targeted at specific sectors within the automotive industry, such as electric vehicle production, exhibit different revenue impacts compared to broader subsidies. However, an unfortunate lack of data makes it challenging to do so.

Conclusion

To conclude, the analysis conducted highlights the nuanced relationship between governmental intervention and industry outcomes, underscoring both the strategic necessity and the inherent inefficiencies of subsidy programs. While subsidies have undeniably facilitated technological advancements in the 2008-2023 period in the USA, particularly in electric vehicle production, their reactive nature often reflects broader economic vulnerabilities rather than proactive industrial strengthening. Empirical findings, such as the relatively moderate R-squared values and the lack of consistent predictive power in Granger causality tests, illustrate the difficulty in isolating subsidies as a singular driver of competitiveness or revenue generation. Instead, the data suggests that subsidies often serve as a buffer against economic downturns, with their impact more pronounced in addressing short-term demand elasticity than in fostering long-term structural change. The disparity in outcomes across regions further reflects the importance of tailored, context-specific subsidy frameworks, rather than uniform application. The broader implications of this research emphasize the need for strategic alignment in subsidy allocation, targeting areas with the potential for maximal socioeconomic and technological impact. The insights drawn highlight the importance of integrating subsidies into a cohesive policy framework that balances competition, innovation, and economic resilience. Ultimately, while subsidies remain a cornerstone of governmental intervention, their effectiveness is contingent upon addressing the structural inefficiencies and strategic misalignments that currently limit their transformative potential.

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