Free trade and environmental standards in the solar panel industry.

Dr. Camilla Jensen

7/29/2018

Preliminary draft - please do not quote! The data used in this paper is only a small sample of the final dataset.

Abstract

Using the hedonistic pricing method, the paper investigates the hypothesis that buyers only partially factor in differences in quality or standards in the international marketplace for wafers. The present result are only preliminary and based on a biased sub-sample of the full dataset. Preliminary results support the proposition that standards when proximated by product warranties are only partially factored into the price-quality relationship. Using the instrumental variable and systems of equation approaches with the hedonistic pricing method render support for the hypothesis and that choice in this industry is anchored in a country-of-origin effect which could owe to differences in local producer and consumer cultures. Accounting for the country-of-origin effect a one year increase in product warranty leads to a price increase of around 15-25%.

Keywords: Sustainability, standards, country-of-origin, quality, durability, wafer industry

---

Introduction (background)

While standards in practise are highly important to the functioning of the global trading system, the role and emergence of standards has been relatively ignored by international economists. In the neoclassical trade theories standards do not feature as important since a central assumption of that paradigm is that goods and producers are homogenous. Standards have often been treated as equivalent to red tape or non-tariff barriers in the literature (Anderson and Wincoop, 2004). But significant events over the last two decades have taught us differently and that standards may be both necessary and lead to better outcomes in the trading system even to the extent that substitute mechanisms for standards have emerged through voluntary adoption of standards such as the community based ISO system or privately based CSR programs (see e.g. Jackson and Apostolakou, 2010). Many products and new service designs also involve the implicit consumption of standards e.g. when we choose or self-select attributes (both objective and hedonistic) including country-of-origin aspects of the goods and services consumed (Verlegh and Steenkamp, 1999).

In the new trade theories there is the possibility that standards can take on increasing importance with the alleviation of the assumption of homogenous producers. Standards have been implicitly treated for example in the literature that centers on price-quality ladders in international trade if it is assumed that higher quality embodies higher standards (Feenstra and Romalis, 2014, Antoniades, 2015). However, the exact role that standards have in the international trading system is still not clear and with globalisation standards may increasingly be impacted by institutions that prevail in other countries than our own. This invasion of global politics into our private lives and when making choices as consumers may be one of the factors behind the rise in discontent with globalisation and the current international trading system (Rodrik, 2011).

Standards themselves may vary both across sectors and the substance areas that the standards seek to regulate such as e.g. the environment, labour, health, financial stability etc. Hence the need to take both a sectoral and substance focus and through such particular cases inquire into the nature, role and origin of standards (Maskus, 2002).

The potential impact that standards may have on trade

The importance of standards setting bodies and cultures has been apparent for many centuries including among the civilisations and cultures along famous trade routes such as the Silk Road and in the Hanseatic League. Here standards often emanated from affinity group regulation that had emerged over longer periods of time (Epstein, 2006, Bozeman, 2017). Such regulations could be one of the main explanatory factors behind the consolidation of a specific geographically confined but extremely flourishing network of traders (Epstein, 2006). With the arrival of new technological paradigms such as IT, new public management concepts such as nudging, new behavioural aspects of business such as CSR and new business models based on digitized service designs, the present trading system has seen an unparalleled move towards self-governance. Relatively little is known about the consequences of self-governance for producers, consumers and governments (Delmas, 2002).

Research objectives

The objective in the present paper is to look at the implications of self-governance for standard setting in one isolated industry case. In solar panels, standards are quite important for environmental outcomes and in particular with respect to durability (Cooper, 1994, Jensen, 2017), since very short-lived solutions may have a net-negative balancing effect on the environment - e.g. the very act of producing the panels may pollute more than the pollution they will eventually evade over their life. In addition buying a solar panel is a complex, uncertain and non-transparent decision-making process (Ansar and Sparks, 2009). Solar panels is an area where there is extensive international trade (Algieri, Aquino and Succurro, 2011) and this trade is more or less unregulated in the aspect of the environmental standards and solutions the present system renders to end consumers and society (Solangi et al, 2011, Curran, 2015).

Research questions

The broader research question posed is whether self-governance in the wafer industry case leads to a more and more differentiated (lack of emerging global standards) or less and less differentiated (presence of emerging global standards) response among producers on the price-quality dimension over time and whether the direction of emerging standards is good or bad news for the environment?

Prior research shows that Silicon wafers emerged as the dominant design following a shakeout period (Furr and Kapoor, 2018). Kapoor and Furr (2015) also find that surviving firms in the wafer industry exhibit superior technological performance. However, this research on technology standards does not encompass any normative or public policy perspective and there is no attention paid to price-quality dimensions or differences in producer and consumer cultures across countries. Nor does the research address the international dimension of the industry, except that the authors demonstrate with a dummy that chinese producers are less likely to exit the industry compared to producers from other countries (Furr and Kapoor, 2018).

With the present paper and data it is only possible to make some initial steps towards answering this greater research question, in particular the available and currently only cross sectional dataset on solar panels makes it possible to answer the following more specific research questions:

- What is the influence of the country-of-origin (original place of production of the brand) on the solar panel standards?
- What is the influence of the firm or the brand on standards?
- Does the response depend on whether the brand is produced by an independent local company, an OEM manufacturer or a foreign subsidiary?
- Is the response different for brands that are produced by firms with and without explicit CSR programs in the area of sustainability?
- How do standards factor into the price-quality relationship? In other words, do consumers factor in implicit standards such as durability when making their choices?

Data

The data is being recorded from an international database that contains present and historical information about solar panel producers worldwide. Producers self-subscribe to the database and thereby contribute to an online community and marketplace that is focused on the solar panel industry.

Using the database and websites of individual manufacturers the research makes use of all or some of the variables described below from these secondary and archival data sources. The recording of the data follows a protocol, where only the first part of the protocol has been completed for the present version of the paper. The second part of the protocol is anticipated to add 50-100 more observations to the dataset. The third part will then expand the dataset with a factor of around 10, rendering a total of at least 1,000 observations. Currently the data gathering process cannot be automated.

Protocol cycle:

1. Record all firms listed with prices in the Company Directory (110 companies)
2. Record additional firms with prices in the Product Directory aiming to stratify the sample by country of origin of the wafer producers (up to 90 additional firms)
3. Expand the individual product recordings by brand and producer to using a weighting scheme that reflects the relative size or weight of each producer in the marketplace according to information about staff and/or annual output in capacity (between 2-10 products per firm)

The current version of the dataset is heavily biased towards firms that register with the Company Directory.

Dependent variables

1. Durability (D) - The life of the solar panel proxied by the length of the product warranty
2. Price (P) - The price of the solar panel quoted in Euros per watt Peak

Main explanatory variables (of Durability)

3. Brand (Brand) - The brand and/or name of manufacturer producing the solar panel
4. Location (Loc) - The location (country, for China also Province) where the solar panel is produced
5. Owner (Owner) - Factor variable registering whether the company is an independent local company, an OEM manufacturer or a foreign subsidiary
6. Country-of-origin (COO) - entered as a dummy of 1 multiplied with the country-of-origin if it is different from the location of production
7. Entry (YoE) - The year the firm entered into the solar panel industry
8. Size (Size) - The size of the producer proxied either by the number of staff or the annual cumulative production in measured in annual Mega Watt output of sold wafers

Supplementary quality (sensory) variables

9. Certifications (Cert) - Dummy variables seperately or in combination when producer has IEC, UL and/or JET certifications
10. Reviews (Rev) - Dummy variable for when customers have entered positive reviews of the producer
11. Sellers (Sell) - Number of recognised sellers that distribute the brand worldwide

Main technical (objective) variables

12. Type (Type) - The type of panel, where the main types available are mono or poly crystalline panels
13. Power (Power) - The effect measured in watt Peak
14. Efficiency (Eff) - Solar irradiance-to-electricity conversion efficiency measured in percentage of the theoretical maximum
15. Weight (Weight) - The weight of the panel which proxies other technical characteristics

Other variables

16. Year (YoO) - The year of the observation which refers to the last update by the producer in the database to ensure that the price information is synchronised in the time aspect

```
##
## Table 1 - Descriptive Statistics
## ===============================================================================
## Statistic    N    Mean    St. Dev.     Min    Pctl(25)  Pctl(75)     Max
## -------------------------------------------------------------------------------
## Size        72  1,368.069 4,120.575  12.000    115.000   512.500  30,000.000
## Output      51    622.471 1,655.669   6.000    190.000   500.000  12,000.000
## Established 63  2,005.476   10.353  1,967.000 2,005.000 2,012.000 2,017.000
## Year        110 2,017.718    0.452    2,017     2,017     2,018     2,018
## Price       110    1.696    11.267    0.004     0.272     0.375    115.000
## Power       110  217.900   105.192      1       162.5      290       360
## Efficiency  95    15.717     2.214    1.280    15.330    16.850    18.800
## Weight      101   17.022     7.106    0.500    15.600    22.000    30.000
## Warranty    110    8.700     5.874      0         5        12        30
## Sellers     110   11.591    56.985      0         0         2        539
## lPrice      110    4.061     1.231    0.325     4.083     4.513    10.415
## -------------------------------------------------------------------------------
```

Methodology

The hedonistic price method which incorporates both objective and sensory characteristics of goods has been applied both to durable goods such as automobiles (Griliches, 1961) and consumer goods such as in particular wine (see e.g. Combris, Lecocq and Visser, 1997). It has also been a popular method in research about the housing market (see e.g. Taylor, 2003). The methodology for testing the relationship between standards, quality aspects of solar panels (e.g. similar to sensory characteristics in the perspective that we do not know how many of the characteristics are received and treated by buyers and consumers of wafers) and their interaction with pricing lends on this same method. Two different models are estimated in the paper.

The first model is very simple and merely seeks to explain differences in the main standardisation aspect of solar panels that is observable and of importance to the environment, which is the durability aspect:

$$Dur_i = Brand_i + Loc_i + Owner_i + COO_i + YoE_i + Size_i$$

The second model incorporates the aspect of price and relates either to durability or more broadly to different quality aspects of the wafer to its price, using the first model as the second equation in SUR, 2SLS and 3SLS estimations:

$$P_i = Type_i + Power_i + Eff_i + Weight_i + Dur_i + Brand_i + Loc_i + Owner_i + COO_i + YoE_i + Size_i + YoO_i$$

$$Dur_i = Brand_i + Loc_i + Owner_i + COO_i + YoE_i + Size_i$$

$$P_i = Type_i + Power_i + Eff_i + Weight_i + Dur_i + Cert_i + Rev_i + Sell_i + Brand_i + Loc_i + Owner_i + COO_i + YoE_i + Size_i + Y$$

$$Dur_i = Brand_i + Loc_i + Owner_i + COO_i + YoE_i + Size_i$$

Expected results and limitations

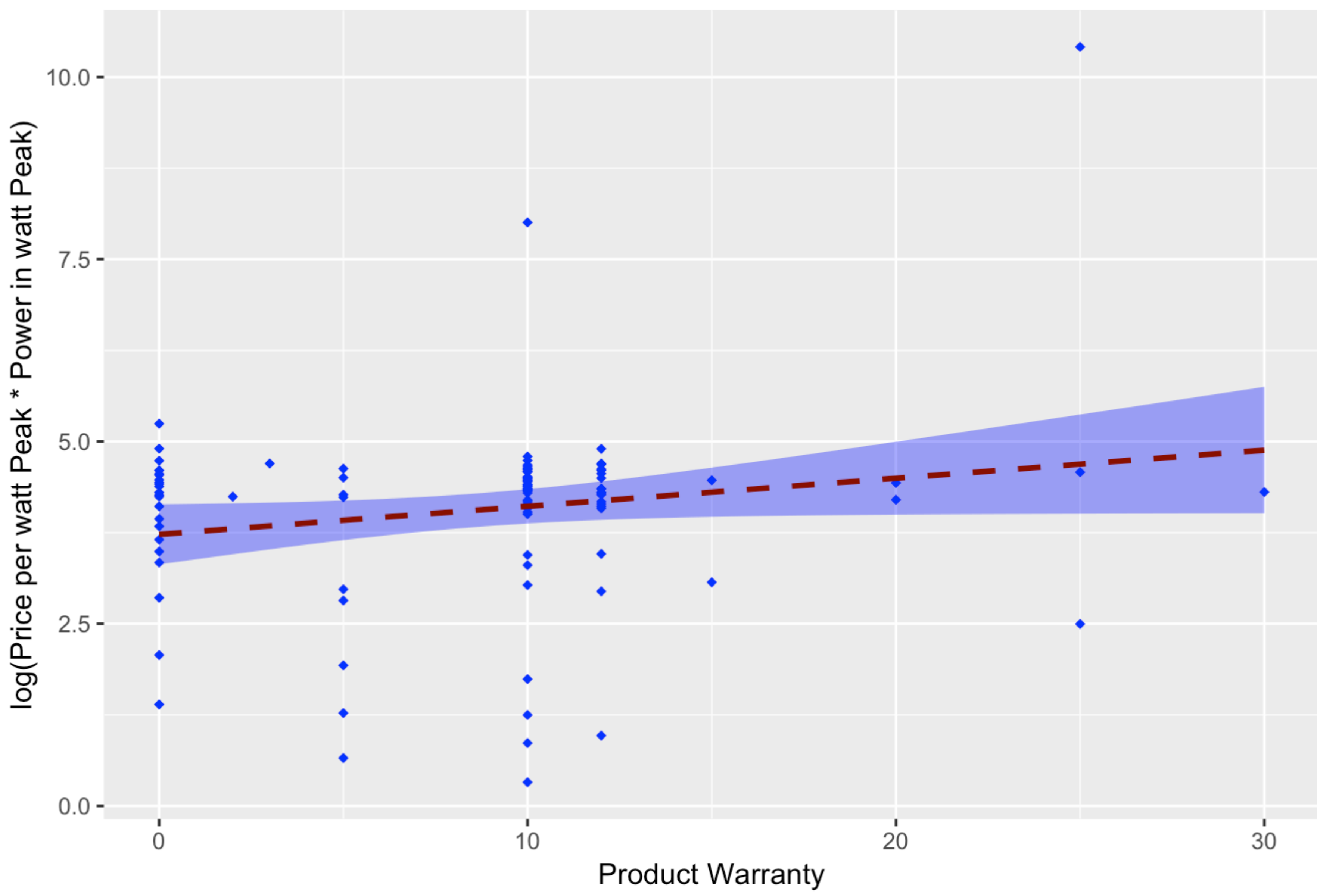
It is expected that durability will vary by country-of-origin due to different prevailing producer cultures and the general lack of central governance. It is also expected that firms with explicit CSR programs will exhibit higher standards indpendent of the country-of-origin effect (since the country-of-origin effect can also have roots in differences in national environmental legislation). In terms of the price-quality relationship it is expected that consumers only partially factor in standards when making buying decisions and that prevailing market information will mirror this situation. Hence the free market and mechanisms of self governance cannot solve for the two fundamental market failure problems in this case. Where the market failures concern differences or clashes betweeen institutions including producer and consumer cultures (which indirectly are a sign of different valuation methods and schemes of producers and consumers) and the inability of consumers to account for all direct and indirect externality aspects of their consumption due to incomplete or non-transparent information about the product.

The current research has several important limitations and therefore mainly serves to complement other research focusing on different aspects of standards such as longitudinal studies of dominant designs or more classical studies of the evolving comparative advantages of industries in international trade. The present research is purely based on a cross-section, price-list type of information. It is an assumption that these price-lists summarise the information that lies behind free market-based equilibrium pricing in the international trading system. The main advantage of this data is that the research focuses on firm-level data whereby it is possible to account for both country- and firm-level type of effects in the same research design.

Preliminary results

First separate OLS estimates are obtained for single equations, at the moment the number of explanatory factors used are limited due to the relatively low number of observations. However, the current version of the equations demonstrate the basic ideas. We are mainly interested in the effect that the power warranty (measured in number of years) has on price. Notice that in these equations price is panel or wafer price, e.g. the logarithm to price*power is adopted as a better dependent variable compared to the prices quoted in per watt Peak. See also Figure 1.

Figure 1 - Wafer price and quality



Initial results with single equations demonstrate some impact of durability or length of warranty on the quoted wafer prices. Hence market prices do to some extent reflect product quality in the wafer industry compared for example to true hedonistic pricing results where such an effect has not been documented (Combris, Lecocq and Visser, 1997). Similar results have been obtained for other consumer durables such as automobiles (Griliches, 1961).

However, when adding the country of the producer, the effect of quality disappears. This suggests that pricing is embedded in the country-of-origin factor as a signal of quality rather than in the technical features of the product such as its guarantees or product warranties.

```
##
## Call:
## lm(formula = lPrice ~ Warranty + Type + factor(Year) + Efficiency +
##     Weight)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.4361 -0.2459 -0.0130  0.2138  5.0294
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)      -0.28637    0.82585  -0.347 0.729671
## Warranty          0.05109    0.02126   2.403 0.018564 *
## TypePoly         -0.12736    0.27381  -0.465 0.643085
## factor(Year)2018 -0.10592    0.24726  -0.428 0.669528
## Efficiency        0.19994    0.05502   3.634 0.000489 ***
## Weight            0.05341    0.01896   2.817 0.006079 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.9936 on 81 degrees of freedom
##   (23 observations deleted due to missingness)
## Multiple R-squared:  0.3818, Adjusted R-squared:  0.3436
## F-statistic:    10 on 5 and 81 DF,  p-value: 1.765e-07
```

```
##
## Call:
## lm(formula = lPrice ~ Warranty + Type + factor(Year) + Efficiency +
##     Weight + Country)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.08433 -0.15543  0.04749  0.23223  2.61442
##
## Coefficients:
##                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)       0.9344741  0.9515861   0.982 0.329473
## Warranty         -0.0007293  0.0169142  -0.043 0.965732
## TypePoly         -0.2248070  0.2017193  -1.114 0.268896
## factor(Year)2018 -0.2434187  0.1943857  -1.252 0.214648
## Efficiency        0.1627866  0.0396756   4.103 0.000109 ***
## Weight            0.0677602  0.0137859   4.915 5.63e-06 ***
## CountryBahrain    5.6044876  1.0181462   5.505 5.72e-07 ***
## CountryChina     -0.4020410  0.7116273  -0.565 0.573907
## CountryGermany   -0.1781322  0.8127177  -0.219 0.827147
## CountryIndia     -2.0204676  0.8888211  -2.273 0.026086 *
## CountryIndonesia -0.3485442  0.9987374  -0.349 0.728148
## CountryRomania    0.1679108  0.8593474   0.195 0.845651
## CountrySpain      1.5800688  0.8193567   1.928 0.057858 .
## CountryTaiwan    -0.3878248  0.8806237  -0.440 0.661006
## CountryTurkey    -0.4116188  1.0118211  -0.407 0.685389
## CountryUSA        0.0215561  0.9951847   0.022 0.982780
## CountryVietnam   -0.3103113  0.8229312  -0.377 0.707255
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7008 on 70 degrees of freedom
##   (23 observations deleted due to missingness)
## Multiple R-squared:  0.7342, Adjusted R-squared:  0.6734
## F-statistic: 12.08 on 16 and 70 DF,  p-value: 2.412e-14
```

```
##
## Call:
## lm(formula = Warranty ~ cc + factor(Year))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.6178 -1.5000  0.3822  2.3822 20.3822
##
## Coefficients:
##                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)       1.046e-14  5.460e+00   0.000  1.00000
## ccARM             9.405e+00  7.837e+00   1.200  0.23316
## ccAUS            -1.720e-14  7.721e+00   0.000  1.00000
## ccBHR             2.241e+01  7.837e+00   2.859  0.00526 **
## ccCHE             9.405e+00  7.837e+00   1.200  0.23316
## ccCHN             7.023e+00  5.586e+00   1.257  0.21187
## ccDEU             1.027e+01  6.367e+00   1.613  0.11018
## ccESP             8.270e+00  6.367e+00   1.299  0.19724
## ccIDN             7.405e+00  7.837e+00   0.945  0.34716
## ccIND             1.667e+00  6.304e+00   0.264  0.79208
## ccJPN            -6.540e-14  7.721e+00   0.000  1.00000
## ccROU             8.405e+00  6.820e+00   1.232  0.22091
## ccTUR             1.200e+01  7.721e+00   1.554  0.12357
## ccTWN             7.500e+00  6.687e+00   1.122  0.26493
## ccUSA             9.405e+00  7.837e+00   1.200  0.23316
## ccVGB            -2.595e+00  7.837e+00  -0.331  0.74131
## ccVNM             7.385e-01  6.445e+00   0.115  0.90903
## factor(Year)2018  2.595e+00  1.341e+00   1.935  0.05609 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 5.46 on 92 degrees of freedom
## Multiple R-squared:  0.2709, Adjusted R-squared:  0.1362
## F-statistic: 2.011 on 17 and 92 DF,  p-value: 0.01818
```

Next was tested the possibility that the quality factor is endogenous or better explained by country of the producer using an instrumental variables approach. It was also investigated using the Hausman test for endogeneity whether *Warranty* could be considered to be an endogenous factor in a potential system of equations. The results reported below render relatively strong support for these propositions. Using an instrumental variables approach increases the impact of quality on product price in this case with a factor of 5. Adding additional instruments such as the availability of product certifications or the number of international sellers that market the product (besides country e.g. overidentified case) does not alter the results. The Hausman test gives a p-value of less than 0.01 suggesting that some element of endogeneity is highly likely in this case.

```
##
## Call:
## ivreg(formula = lPrice ~ Warranty + Type + factor(Year) + Efficiency +
##     Weight | Type + Year + Efficiency + Weight + cc)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -5.056055 -0.544341 -0.005429  0.418793  4.032155
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)      -1.91004    1.26467  -1.510 0.134857
## Warranty          0.24176    0.06493   3.723 0.000362 ***
## TypePoly          0.27065    0.40476   0.669 0.505605
## factor(Year)2018 -0.53199    0.37199  -1.430 0.156532
## Efficiency        0.23558    0.07841   3.004 0.003539 **
## Weight            0.02274    0.02832   0.803 0.424416
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.402 on 81 degrees of freedom
## Multiple R-Squared: -0.2319, Adjusted R-squared: -0.3079
## Wald test: 7.214 on 5 and 81 DF,  p-value: 1.25e-05
```

```
##
## Call:
## ivreg(formula = lPrice ~ Warranty + Type + factor(Year) + Efficiency +
##     Weight | Type + Year + Efficiency + Weight + cc + IEC)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -5.058147 -0.544540 -0.005519  0.418901  4.031882
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)      -1.91095    1.26502  -1.511 0.134781
## Warranty          0.24186    0.06495   3.724 0.000361 ***
## TypePoly          0.27088    0.40488   0.669 0.505374
## factor(Year)2018 -0.53223    0.37210  -1.430 0.156463
## Efficiency        0.23560    0.07843   3.004 0.003546 **
## Weight            0.02272    0.02833   0.802 0.424894
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.403 on 81 degrees of freedom
## Multiple R-Squared: -0.2326, Adjusted R-squared: -0.3086
## Wald test: 7.212 on 5 and 81 DF,  p-value: 1.253e-05
```

```
## [1] 0.007992404
```

Finally the two equations are investigated in a system of equations. Given the low number of observations currently it further limits the inclusion of explanatory variables. For example, it is not possible at the moment to include important explanatory variables such as *Efficiency* and *Weight* into the system which does reduce the reliability of the present results.

The better results are obtained with the 3SLS results according to the overall system-fit reported (e.g. McElroy R^2). Differences in obtained coefficient estimates do not differ much across the 2SLS and 3SLS specifications. According to the system results, a one year increase in warranty increases the price with 15% rather than 5% (but the difference is less than what the IV regressions suggest) once it is factored into the relationship that warranties are not evaluated independently from the country-of-origin of the product.

The results obtained overall are quite consistent. However, outlier observations may have a large influence on the results obtained at the moment since the sample is unbalanced in terms of country observations and will be sought stratified according to representation of producers in the Product Directory rather than the Company Directory since the Company Directory is strongly biased in its representation of countries.

```
##
## systemfit results
## method: 2SLS
##
##          N  DF  SSR detRCov   OLS-R2 McElroy-R2
## system 220 196 2930 42.3599 0.253763   0.367593
##
##       N  DF      SSR      MSE    RMSE        R2    Adj R2
## eq1 110 106  198.077  1.86865 1.36698 -0.198484 -0.232404
## eq2 110  90 2731.926 30.35473 5.50951  0.273636  0.120293
##
## The covariance matrix of the residuals
##          eq1      eq2
## eq1  1.86865 -3.78977
## eq2 -3.78977 30.35473
##
## The correlations of the residuals
##           eq1       eq2
## eq1  1.000000 -0.503195
## eq2 -0.503195  1.000000
##
##
## 2SLS estimates for 'eq1' (equation 1)
## Model Formula: lPrice ~ Warranty + Type + factor(Year)
## Instruments: ~Type + Year + Country + Sellers + IEC
##
##                    Estimate Std. Error  t value   Pr(>|t|)
## (Intercept)       3.1231771  0.4257191  7.33624 4.6314e-11 ***
## Warranty          0.1513934  0.0502192  3.01465  0.0032195 **
## TypePoly          0.2266233  0.3253127  0.69663  0.4875578
## factor(Year)2018 -0.5994366  0.3367995 -1.77980  0.0779739 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.366985 on 106 degrees of freedom
## Number of observations: 110 Degrees of Freedom: 106
## SSR: 198.076563 MSE: 1.868647 Root MSE: 1.366985
## Multiple R-Squared: -0.198484 Adjusted R-Squared: -0.232404
##
##
## 2SLS estimates for 'eq2' (equation 2)
## Model Formula: Warranty ~ cc + factor(Year) + Sellers + IEC
## Instruments: ~Type + Year + Country + Sellers + IEC
##
##                      Estimate   Std. Error  t value  Pr(>|t|)
## (Intercept)      -5.42353e-03  5.50952e+00 -0.00098 0.9992167
## ccARM             9.31273e+00  7.91069e+00  1.17723 0.2422065
## ccAUS             3.55743e-13  7.79163e+00  0.00000 1.0000000
## ccBHR             2.23127e+01  7.91069e+00  2.82058 0.0058969 **
## ccCHE             9.26392e+00  7.91316e+00  1.17070 0.2448111
## ccCHN             6.86370e+00  5.65421e+00  1.21391 0.2279584
## ccDEU             9.98554e+00  6.44815e+00  1.54859 0.1249897
## ccESP             8.13798e+00  6.43040e+00  1.26555 0.2089412
## ccIDN             7.24049e+00  7.98689e+00  0.90655 0.3670670
## ccIND             1.64620e+00  6.37448e+00  0.25825 0.7968045
## ccJPN            -5.42353e-03  7.79163e+00 -0.00070 0.9994462
## ccROU             8.26305e+00  6.90302e+00  1.19702 0.2344424
## ccTUR             1.19332e+01  7.88385e+00  1.51362 0.1336252
## ccTWN             7.50000e+00  6.74775e+00  1.11148 0.2693213
## ccUSA             8.79207e+00  7.98559e+00  1.10099 0.2738362
## ccVGB            -2.68727e+00  7.91069e+00 -0.33970 0.7348732
## ccVNM             6.46062e-01  6.50712e+00  0.09929 0.9211324
## factor(Year)2018  2.69269e+00  1.36866e+00  1.96740 0.0522170 .
## Sellers           5.42353e-03  9.62461e-03  0.56351 0.5744911
## IECYES            6.68137e-02  1.20235e+00  0.05557 0.9558081
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 5.509513 on 90 degrees of freedom
## Number of observations: 110 Degrees of Freedom: 90
## SSR: 2731.925986 MSE: 30.354733 Root MSE: 5.509513
## Multiple R-Squared: 0.273636 Adjusted R-Squared: 0.120293
```

```
##
## systemfit results
## method: 3SLS
```

```
##
##          N  DF     SSR detRCov   OLS-R2 McElroy-R2
## system 220 196 3128.71 37.5758 0.203155   0.466695
##
##       N  DF      SSR      MSE    RMSE        R2    Adj R2
## eq1 110 106  198.802  1.87549 1.36948 -0.202871 -0.236915
## eq2 110  90 2929.907 32.55453 5.70566  0.220997  0.056541
##
## The covariance matrix of the residuals used for estimation
##          eq1      eq2
## eq1  1.86865 -3.78977
## eq2 -3.78977 30.35473
##
## The covariance matrix of the residuals
##          eq1     eq2
## eq1  1.87549 -4.8456
## eq2 -4.84560 32.5545
##
## The correlations of the residuals
##           eq1       eq2
## eq1  1.000000 -0.620133
## eq2 -0.620133  1.000000
##
##
## 3SLS estimates for 'eq1' (equation 1)
## Model Formula: lPrice ~ Warranty + Type + factor(Year)
## Instruments: ~Type + Year + Country + Sellers + IEC
##
##                    Estimate Std. Error  t value   Pr(>|t|)
## (Intercept)       3.1739077  0.4237191  7.49059 2.1517e-11 ***
## Warranty          0.1515509  0.0502190  3.01780  0.0031889 **
## TypePoly          0.0485428  0.2913667  0.16660  0.8679991
## factor(Year)2018 -0.6156271  0.3365425 -1.82927  0.0701702 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.369484 on 106 degrees of freedom
## Number of observations: 110 Degrees of Freedom: 106
## SSR: 198.80165 MSE: 1.875487 Root MSE: 1.369484
## Multiple R-Squared: -0.202871 Adjusted R-Squared: -0.236915
##
##
## 3SLS estimates for 'eq2' (equation 2)
## Model Formula: Warranty ~ cc + factor(Year) + Sellers + IEC
## Instruments: ~Type + Year + Country + Sellers + IEC
##
##                     Estimate  Std. Error  t value   Pr(>|t|)
## (Intercept)       3.06724219  4.82927876  0.63513 0.52695210
## ccARM             7.23489761  6.90107892  1.04837 0.29727447
## ccAUS            -0.65127922  6.73331430 -0.09672 0.92315992
## ccBHR            27.42440727  7.17012564  3.82482 0.00024099 ***
## ccCHE             6.40484169  6.90325663  0.92780 0.35599287
## ccCHN             2.91079148  4.93636025  0.58966 0.55689372
## ccDEU             6.38119204  5.66323902  1.12677 0.26283327
## ccESP             8.04305975  5.61421663  1.43262 0.15542976
## ccIDN             3.94426695  6.94534462  0.56790 0.57151639
## ccIND            -1.90170276  5.52112061 -0.34444 0.73131787
## ccJPN             1.12278046  6.75930628  0.16611 0.86844390
## ccROU             5.60961742  6.02664997  0.93080 0.35444611
## ccTUR             6.40016808  6.91279244  0.92584 0.35700300
## ccTWN             4.89159243  5.88672743  0.83095 0.40819937
## ccUSA             5.20310342  6.96461706  0.74708 0.45696458
## ccVGB            -3.60471521  6.87329788 -0.52445 0.60125351
## ccVNM             0.02095576  5.65122514  0.00371 0.99704951
## factor(Year)2018  2.75816695  1.32324119  2.08440 0.03995710 *
## Sellers           0.00454305  0.00842337  0.53934 0.59098484
## IECYES            1.06210506  1.03919657  1.02204 0.30949928
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 5.705657 on 90 degrees of freedom
## Number of observations: 110 Degrees of Freedom: 90
## SSR: 2929.907436 MSE: 32.554527 Root MSE: 5.705657
## Multiple R-Squared: 0.220997 Adjusted R-Squared: 0.056541
```

Perspectives

As the datatset is expanded into a panel it will also be possible to answer the following research questions:

- Does the price-quality variation increase or decrease over time?
- Is the response over time an indication of an increase in or improvement in standards towards a more sustainable production and adoption of solar panel technology? In other words does product durability improve over time?

However, these questions are left for future research papers to address as the work with the data progresses.

References

Algieri, B., Aquino, A., & Succurro, M. (2011). Going ???green???: trade specialisation dynamics in the solar photovoltaic sector. Energy Policy, 39(11), 7275-7283.

Anderson, J. E., & Van Wincoop, E. (2004). Trade costs. Journal of Economic literature, 42(3), 691-751.

Combris, P., Lecocq, S., & Visser, M. (1997). Estimation of a hedonic price equation for Bordeaux wine: does quality matter?. The Economic Journal, 107(441), 390-402.

Ansar, J., & Sparks, R. (2009). The experience curve, option value, and the energy paradox. Energy Policy, 37(3), 1012-1020.

Antoniades, A. (2015). Heterogeneous firms, quality, and trade. Journal of International Economics, 95(2), 263-273.

Bozeman, A. B. (2017). Politics and culture in international history: from the ancient Near East to the opening of the modern age. Routledge.

Cooper, T. (1994). The durability of consumer durables. Business Strategy and the Environment, 3(1), 23-30.

Curran, L. (2015). The impact of trade policy on global production networks: The solar panel case. Review of International Political Economy, 22(5), 1025-1054.

Delmas, M. A. (2002). The diffusion of environmental management standards in Europe and in the United States: An institutional perspective. Policy Sciences, 35(1), 91-119.

Epstein, E. M. (2007). The good company: Rhetoric or reality? Corporate social responsibility and business ethics redux. American business law journal, 44(2), 207-222.

Feenstra, R. C., & Romalis, J. (2014). International prices and endogenous quality. The Quarterly Journal of Economics, 129(2), 477-527.

Furr, N., & Kapoor, R. (2018). Capabilities, technologies, and firm exit during industry shakeout: Evidence from the global solar photovoltaic industry. Strategic Management Journal, 39(1), 33-61.

Griliches, Z. (1961). Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change," in The Price Statistics of the Federal Government, G. Stigler (chairman). Washington DC: Government Printing Office.

Jackson, G., & Apostolakou, A. (2010). Corporate social responsibility in Western Europe: an institutional mirror or substitute?. Journal of Business Ethics, 94(3), 371-394.

Jensen, C. (2017). International trade in infant industries: A dynamic analysis of different trade policy instruments and their implications for sustainable consumption. management revue, 28(1), 121-148.

Kapoor, R., & Furr, N. R. (2015). Complementarities and competition: Unpacking the drivers of entrants' technology choices in the solar photovoltaic industry. Strategic Management Journal, 36(3), 416-436.

Maskus, K. E. (2002). Regulatory standards in the WTO: Comparing intellectual property rights with competition policy, environmental protection, and core labor standards. World Trade Review, 1(2), 135-152.

Rodrik, D. (2011). The globalization paradox: why global markets, states, and democracy can't coexist. Oxford University Press.

Solangi, K. H., Islam, M. R., Saidur, R., Rahim, N. A., & Fayaz, H. (2011). A review on global solar energy policy. Renewable and sustainable energy reviews, 15(4), 2149-2163.

Taylor, L. O. (2003). The hedonic method. In A primer on nonmarket valuation (pp. 331-393). Springer, Dordrecht.

Verlegh, P. W., & Steenkamp, J. B. E. (1999). A review and meta-analysis of country-of-origin research. Journal of economic psychology, 20(5), 521-546.