The Informativeness of the Technical Conversion Factor for the Price Ratio of Processing Livestock

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Abstract

The technical conversion factor (TCF) is a survey-based estimate of the percentage of carcass weight obtained per unit of live weight. Practitioners and researchers have used it to predict the corresponding price ratio (PR). We use both in-sample regressions and out-of-sample forecasting analysis to test the validity of this approach in case of predicting the price effects of processing livestock in Europe. By regressing the PR on the inverse value of the corresponding TCF for a large panel of European countries and animal types, we find a significant positive relation between these variables, which also has economic value in terms of improving out-of-sample forecasting precision. This result is shown to be robust to animal type, year, and country fixed effects. The TCF therefore has predictive value about the corresponding PR.[3]

Keywords

Agriculture, carcass weight, live weight, producer price, pass-through effect

JEL code

C52, Q13

INTRODUCTION

Agricultural production is characterized by a chain of transformations from livestock to consumer products. First, a live animal is slaughtered to get primary carcass parts such as meat, offal, and skin. Then these components are processed to obtain different products such as sausage or lard (FAO, 2011). A detailed understanding of how the processing of livestock affects agricultural prices is of paramount importance for producers and consumers of agricultural products. To achieve this, economic policymakers such as the Food and Agricultural Organization of the United Nations (FAO) use surveys to collect information on the physical efficiency of the processing of livestock and the corresponding price ratios (PRs). They use the so-called technical conversion factor (TCF) to quantify the extraction productivity. In case of livestock, the TCF indicates in percent term the dressed carcass weight that can be extracted per unit

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of the live weight of the slaughtered animal. For example, if there are 100 kg of carcass weight obtained from 200 kg of live weight, the TCF is 0.5.

TCFs are published by the FAO using the information obtained from surveys sent to its member nations (FAOSTAT, 2009). The main objective of TCFs is "to arrive at approximate estimates of the total availability of food in each country, expressed in terms of quantity as well as in terms of calories, protein, and fat" (FAOSTAT, 2009). In recent years, TCFs have been widely applied in research and calculations in different fields. For instance, Lazarus et al. (2014) use TCFs in calculating the carbon footprint for crops and livestock, while Luan et al. (2014) employ the conversion factor in computing land requirements for food in South Africa. OECD-FAO (2015) takes them as factors in constructing prices and quantities for a variety of agricultural products, as well as for performing the Aglink-Cosimo economic model, which analyzes supply and demand of world agriculture. Smith et al. (2016) use the conversion factors to estimate the global dietary supply of nutrients. Chaudhary et al. (2016) use TCFs to obtain the weight of primary crop required for an amount of processed food in their calculations of biodiversity loss due to anthropogenic land. Finally, the FAO has been using TCFs to impute missing observations in agricultural price series (Kirkendall, 2015; Dubey et al., 2016).

In this paper, we analyze TCFs and PRs of the processing of four common types of livestock – namely cattle, pig, chicken, and sheep – in European countries over the period 1969 to 2015. We expect to find a close connection between the TCF and the PR of meat versus live weight, since the TCF corresponds to the physical reality behind the PR of livestock products. We focus on EU member states because they share the so-called Common Agriculture Policy (CAP). Focusing on one integrated geographic region allows us to avoid inter-regional shocks and differences in policy that can affect our analysis. Another reason for choosing the EU area is the availability of high-quality price data at Eurostat and the FAO for a large number of countries and types of livestock, which facilitate our study.

Our first contribution is to provide a descriptive analysis of the relation between the TCF and the producer PRs over the period 1969 to 2015. We combine various sources to create a longitudinal database of both TCFs and producer PRs. The longitudinal time series is unbalanced, because of the many cases in which the data are missing. We analyze the data through summary statistics and a scatter plot, giving a first indication of the positive relation between the TCF and PR.

Our second contribution is to propose and test a simple model to use the TCF to predict the PRs of livestock processing for a product type and country combinations. The model consists of regressing the PR (dependent variable) on the inverse of TCF (ITCF) and three other variables, namely trend (time effect), animal type, and country. We find both in-sample and out-of-sample evidence that the ITCF-based model is useful for the prediction of the PR.

The remainder of this paper is organized as follows. In Section 1, we discuss the characteristics of TCFs and PRs of processing livestock. Section 2 describes our data, while Section 3 explains the methodology. The results are presented in Sections 4 and 5, while the last Section summarizes our main conclusions.

1 THE CHARACTERISTICS OF THE TCF AND THE PR OF PROCESSING LIVESTOCK

1.1 TCF

The TCF of livestock is a measure that indicates in percent term the amount of a product extracted per unit of the originating one. These extraction rates differ across countries and time due to differences in technology, costs, and margins. It is a key statistic determining food prices, by which the FAO keeps track of and monitors the evolution of the TCF.

The FAO's analysis starts with collecting the TCF data by sending out questionnaires to member nations (FAOSTAT, 2009). Since 1960, it has produced three publications about the TCF. The first book published in 1960 presents conversion rates of products in countries around the world. It is the foundation for the second and third publications, in 1972 and in 2009, respectively, with adjusted, extended, and refined contents to increase comprehensiveness and comparability. Although these publications include several levels of transformation of different products, here we focus on only first-level conversion factors of livestock processing.

The last three columns of Table 1 present examples of TCFs of the livestock processing in European countries (members of CAP). As can be clearly seen, extraction productivity differs among animal groups. The first-stage processing of chicken and pig is characterized by higher average TCFs (around 75–77%) compared to those of cattle and sheep, which are approximately 48–54%. Next, to perceive how TCFs evolved over 53 years, we compare the statistics in 2009 with those in 1968 and 1957. We find that for most cases, the conversion rates are stable over time.

Notable exceptions include TCFs of pig in the Czech Republic and TCFs of chicken in Italy.

1.2 The PR of processing livestock

The PR of livestock processing refers to the relation between prices received by the producers when selling live animal and meat. Investigating this PR for several countries and animal types jointly is complementary to previous studies, which have either examined the consumer PRs of agricultural commodities or focused on a single animal type. For example, Tveteras and Asche (2008) and Asche et al. (2013) analyze the fishery industry, while Chavas and Holt (1991), Parker and Shonkwiler (2013) and Holt and Craig (2006) investigate the dynamics in hog-to-feed PRs.

In this paper, we research the PRs of livestock in the first transformation level, which turns the live animal into primary components such as meat, offal, fat, and skin (FAO, 2011). Particularly, we focus on the PR of meat. This choice is due to three reasons. First, among all products derived from the carcass, meat has the most important use in human daily consumption (compared to skin, bone, or offal). Second, it accounts for a major part of the carcass. As can be seen in Table 1, between 50% and 75% of the body is meat, depending on the animal type. Third, other components such as skin, bone, offal, and fat have only a negligible economic value compared to meat.

The PR of meat is obtained by dividing the carcass meat price by the live weight price, of which they are measured at the same mass (100 kg normally). Economically, the price of carcass meat should cover all transformation costs, namely the livestock purchasing cost (i.e, the live weight price), the labor and infrastructure costs needed to slaughter the animal, and the profit margin.

1.3 The relation between PR and TCF

The extraction rate (or TCF) is expected to have an inverse relation with the meat PR. When the TCF increases, the PR decreases. To clarify this argument, we consider a stylized numeric example. Assume that for processing livestock, we have a TCF of 0.5, which means with 100 kg of live weight, we can obtain 50 kg of carcass meat. Assume further that the price of 100 kg live weight is ¤100. Then the price of 50 kg carcass meat should at least cover its material costs, which is the price of 100 kg live weight. As such, 50 kg carcass meat has the minimum price of ¤100, and when expressed for the same units of weight, the PR equals at least two. In the same manner, increases in the TCF (e.g. due to higher efficiency in the processing) can be expected to lead to decreases in the PR, and vice versa in the case of a decrease. As such, on average we expect the TCF to be inversely proportional with the PR, whereby the minimum value of the PR is the inverse of the TCF. Henceforth, we call 1/TCF the inverse technical conversion factor (ITCF) and study its relation with the producer PR of processing livestock.

2 DATA

This section includes three main parts. The first part introduces our data source, the Eurostat and the FAO, and how we collect the data. The second section examines how PRs are filtered and paired with ITCFs. After that, we provide some explorative analysis about the PRs and ITCFs.

We collect the data and calculate the PR for four types of livestock – cattle, chicken, pig, and sheep – of the CAP countries. In order to obtain the longest possible time series, the prices of live weight and carcass meat are gathered and combined from Eurostat (2017) and FAOSTAT (2017). These are the prices received by farmers for livestock primary products as collected at the point of initial sale or the first marketing stage (FAOSTAT, 2018; Eurostat, 2018). The furthest data point we can get back to is 1969, while the most recent one is 2015. After matching the live weight prices and carcass meat prices

Table 1 PRs and TCFs

No	Livestock	Country	PR						TCF		
			Period	# Obs	Min	Average	Max	SD	1957	1968	2009
1	Cattle	Belgium	1971–2001	31	1.62	1.77	2.04	0.1	0.54	0.55	0.54
2	Cattle	Denmark	1991–2015	25	1.55	1.74	1.92	0.1	0.5	0.48	0.49
3	Cattle	France	1969–2002	34	1.35	1.46	1.9	0.1	n/a	0.5	0.52
4	Cattle	Greece	1995–2014	20	1.37	1.65	1.82	0.2	n/a	0.5	0.52
5	Cattle	Italy	1969–1999	31	1.56	1.69	2.03	0.1	0.53	0.54	0.55
6	Cattle	Luxembourg	1969–2015	47	1.63	1.71	1.79	0	0.56	0.54	0.54
7	Cattle	Netherlands	1969–1990	22	1.57	1.67	1.75	0	0.52	0.52	0.54
8	Chicken	Austria	1995–2015	21	1.96	2.28	2.41	0.1	n/a	0.8	0.75
9	Chicken	Denmark	1991–2015	25	1.06	1.35	1.49	0.1	0.8	n/a	0.76
10	Chicken	Italy	1969–1999	31	1.18	1.42	1.63	0.1	0.89	n/a	0.75
11	Pig	Austria	1995–2015	21	1.22	1.23	1.26	0	0.79	0.8	0.81
12	Pig	Belgium	1970–2007	38	1.09	1.16	1.21	0	0.78	0.79	0.79
13	Pig	Czech Republic	2004–2015	12	1.27	1.3	1.33	0	n/a	0.82	0.71
14	Pig	Denmark	1973–2015	43	1.23	1.36	1.41	0	0.72	0.72	0.7
15	Pig	Greece	1981–2015	35	0.75	0.98	1.18	0.1	n/a	0.77	0.76
16	Pig	Italy	1969–1999	31	1.02	1.17	1.32	0.1	0.81	0.83	0.79
17	Pig	Luxembourg	1969–2005	37	1.16	1.22	1.31	0	0.87	0.79	0.79
18	Pig	Spain	1986–2015	30	1.42	1.45	1.52	0	n/a	0.8	0.79
19	Pig	UK	1973–2005	33	0.97	1.18	1.34	0.1	n/a	0.74	0.76
20	Sheep	Austria	1995–2015	21	1.91	2.07	2.09	0.1	0.5	0.54	0.53
21	Sheep	Greece	1995–2014	20	2.92	3.57	4.02	0.2	n/a	0.5	0.49

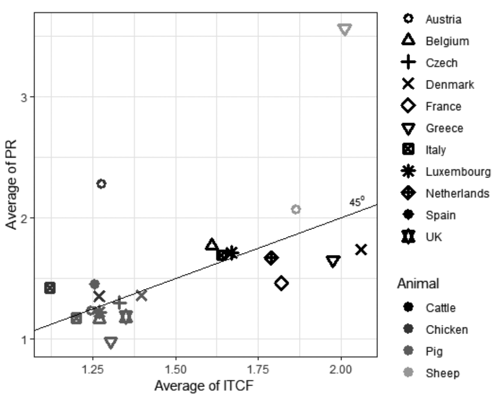
Note: "n/a" denotes that the corresponding data are not available.
Source: Eurostat (2017); FAOSTAT (1960, 1972, 2009, 2017)

and restricting the sample to the country-years that the country is effectively a member of the EU and for which there are more than ten continuous observations, we end up with a sample of 21 usable cases with 608 PR observations. There are 9 cases of pig, 7 cases of cattle, 3 cases of chicken, and 2 cases of sheep. Even though the number of chicken and sheep cases is outnumbered by cattle and pig, their observations account for more than 20% of the total database. Table 1 provides the summary statistics for this sample.

For this sample, we apply the panel unit root test (Kleiber and Lupi, 2011) to test whether the PR is stationary or not. We apply the test on the balanced panel of 21 selected cases. As can be seen in Table 1, each PR series has a different length. Therefore, we subdivide 21 cases into smaller groups based on similarity in data range and perform tests on them. For example, the subgroup with time frames 1969–2002 includes four cases: the cattle PRs of Italy (with data range from 1969 to 1999), the cattle PRs of France (1969–2002), the cattle PRs of Belgium (1971–2001), and the chicken PRs of Italy (1969–1999). A panel unit root test is performed on this subgroup. There is one exception – the pig PRs of the Czech Republic – which has a short data period of 12 years that cannot be paired with others. It is tested independently. Overall, at a 10% significance level, all tests reject the null hypothesis of a unit root and thus conclude at stationarity over the panel.

The selected PR is then paired with the corresponding ITCF, calculated by dividing one with the TCF, which is selected using the last-observation-carried-forward method. For PRs in the range from 1969 to 2008, we pair them with ITCFs obtained using information from the FAO's second publication, which was published in 1972 and provides statistics from 1968. In case these numbers are not available, we use the first publication with data from 1957. For ratios from 2009 to 2015, the ITCFs calculated from information from the third publication are used.

Figure 1 Scatter plots of the average of PRs versus the average of ITCFs



Note: This figure displays the average of PRs in relation to the corresponding average ITCFs of 21 sample cases. The black line is the 45° line.
Source: Authors´ calculations

Figure 1 displays the average of the PRs per country and animal type, in relation with the averages of corresponding ITCFs of the 21 selected cases. The 45° line indicates the reference in which the PR equals with the ITCF. Note that the observations tend to cluster for each animal type, creating disparities among groups. In particular, most chicken and pig indicators stay in lower areas compared to those of cattle and sheep. We thus find a difference in both extraction productivity and PR between animal groups. In fact, the higher TCFs of processing pigs and chickens compared to cattle explain their lower PRs (how TCFs link with PRs has been explained in Section 1.3). We also note that most observations lie along the 45° line, meaning the average PR has a close value to the ITCF. Notable exceptions are the sheep PRs of Greece with an average value of 3.57 while its ITCF is 2.92, or the chicken PRs for Austria with an average of 2.28 – substantially higher than its ITCF of 1.27.

3 METHODOLOGY

The main purpose of our research is to investigate whether the TCF is predictive of livestock price effect, or in other words, can the TCF be used to predict the corresponding livestock PR. We study this question using a panel data regression model that explains the PR using ITCFs, animal type, country, and year fixed effects. Among these variables, the ITCF is our main variable of interest. Our model is applied on a large number of countries and animal groups. It is beyond the scope of our paper to develop a model aiming at deriving causality. Instead, the model used should be interpreted as a predictive model that is useful in the operational setting of having to predict the PR using the TCF. Except for the TCF, all predictive variables used are deterministic and thus straightforward to construct. The model is estimated by ordinary least squares resulting in the best linear prediction given the set of variables used.

The empirical analysis is performed using in-sample and out-of-sample evaluation methods.

3.1 In-sample evaluation

We use nested versions of the following regression model to analyze the determinants of the PRs across observations for various animal groups (indexed by *a*), countries (indexed by *c*) and years (indexed by *t*):

$$\mathrm{PR}_{a,c,t} = \alpha + \alpha_a + \alpha_c + \gamma \mathrm{Trend}_t + \beta\, \mathrm{ITCF}_{a,c,t} + \varepsilon_{a,c,t}\,. \tag{1}$$

In Formula (1), α corresponds to the intercept of the reference category corresponding to the PR of cattle in Denmark. The terms α_a and α_c, respectively, denote the animal type and country group, while $\varepsilon_{a,c,t}$ represents the error term. The value of $ITCF_{a,c,t}$ is calculated from the TCF taken from Table 1. The deterministic trend variable $Trend_t$ takes values from 1 to 47, corresponding to the number of observations in the time series of PRs (1969–2015). In order to exploit the effect of animal group on the predicted PR, we include dummies for pig, chicken, and sheep, while there are 14 country dummies: Austria, Belgium, Czech Republic, Estonia, France, Germany, Greece, Italy, Luxembourg, the Netherlands, Romania, Slovakia, Spain, and the UK. There is therefore no dummy for the animal type cattle and the country Denmark in order to avoid multicollinearity with the intercept. We present our results using robust standard errors, computed using the Arellano (1987) standard errors, which are robust for heteroskedasticity and correlation clustering.

3.2 Out-of-sample evaluation

In order to evaluate the models' accuracy in forecasting the PR, we conduct out-of-sample forecasts using mean absolute forecast error (MAFE) as the criterion. The out-of-sample period is from 2004 to 2015. We estimate the four regression models nested in Formula (1) using an expanding estimation window. The MAFE is defined as:

$$\mathrm{MAFE} = \frac{1}{T-S}\sum_{t=S+1}^{T} |e_t|\,, \tag{2}$$

where T is the total length of the series (608 observations), S is the burn-in period corresponding to the period 1969–2003 (458 observations), and $e_t = PR_t - \widehat{PR}_t$ is the one-step-ahead forecast error. The lower the MAFE, the better is the forecasting performance of the model. We test the significance of the difference in the MAFE between models using the Diebold-Mariano test (Diebold and Mariano, 2002).

4 RESULTS

Our main result is that for all models considered we cannot reject that, in the regression models of the agricultural PR on the corresponding ITCF, there is statistically and economically significant positive coefficient for the ITCF at a 95% confidence interval.

The in-sample and out-of-sample regression results of our main models for PR are reported in Tables 2 and 4. First, we discuss the in-sample parameter estimates and the goodness-of-fit statistics of these models. Then we evaluate the out-of-sample forecasting accuracy in terms of low values for the MAFE. After that, we discuss the robustness tests for which the results are presented in Table 4.

4.1 In-sample results

Let us first study the estimation results for the single-variate regression model in column (1) of Panel A in Table 2. We find that the least squares estimate of the slope coefficient is 1.024 with a robust standard error of 0.087. The ITCF is thus statistically significant at the 95% confidence interval. It is noteworthy that this simple model can already explain 34.6% of the variation in the price-ratios. The near-one value of the ITCF means that when the ITCF increases by one unit, the PR is expected to do the same, ceteris paribus. Importantly, the estimated coefficient remains around one, when controlling in columns (2)–(4) for the effects of animal type, country, and trend. In all specifications considered, the ITCF has an estimated coefficient of around one, and it is statistically significant at 95% confidence level.

Table 2 Determinants of the PR of processing livestocks

Panel A: In-sample regression estimates

	(1)	**(2)**	**(3)**	**(4)**
ITCF	1.024*** (0.087)	1.000*** (0.084)	1.089*** (0.160)	1.140*** (0.162)
Trend		0.005*** (0.001)		–0.002** (0.001)
Chicken			0.582*** (0.110)	0.612*** (0.113)
Pig			0.006 (0.074)	0.023 (0.075)
Sheep			0.920*** (0.122)	0.915*** (0.122)
Austria			0.143 (0.077)	0.164* (0.078)
Belgium			0.259*** (0.051)	0.244*** (0.051)
Czech Republic			0.224*** (0.048)	0.259*** (0.050)
France			–0.146** (0.038)	–0.176*** (0.040)

Table 2 (continuation)

Panel A: In-sample regression estimates

	(1)	(2)	(3)	(4)
Greece			0.159** (0.056)	0.168** (0.056)
Italy			0 . 171 *** (0.051)	0.147** (0.051)
Luxembourg			0.242*** (0.047)	0.231*** (0.047)
Netherlands			0.095* (0.037)	0.052 (0.037)
Spain			0.458*** (0.046)	0.475*** (0.046)
UK			0.079* (0.037)	0.064 (0.035)
Constant	0.008 (0.120)	–0.078 (0.127)	–0.378 (0.120)	–0.398 (0.140)
R^2	0.346	0.361	0.727	0.729
Adjusted R^2	0.345	0.359	0.720	0.722

Panel B: Out-of-sample forecast precision results

	(1)	(2)	(3)	(4)
MAFE for forecasting PR	0.354	0.388	0.281	0.282

$*p < 0.1$; $**p < 0.05$; $***p < 0.01$

Note: This table presents in-sample and out-of-sample results of four regression models nested in Formula (1), our main explaining factor for the dependent variable PR is ITCF.
Source: Authors´ calculations

The most parsimonious model seems to be model (3), which compared to model (4), omits the trend variable but has similar goodness of fit. Note that in the model (4), the contribution of the trend variable is small compared to others with a coefficient equal to –0.002. Meanwhile, animal type and country variables are big contributors to the R^2. The single-variate model explains 34.6% of the variation in the price-ratios, while model (3) can describe 72.7% of the PR variability. This confirms the joint predictive power of animal type and country in explaining the producer PR of livestock, in addition to the ITCF.

4.2 Forecasting precision results

The out-of-sample forecasting performance of the four regression models is evaluated using the MAFE evaluation criterion, for which the results can be found in Panel B of Table 2. In general, the lower the MAFE, the better the forecast precision provided by the model. We can see that the single-variate model in column (1) of Table 2 returns a MAFE of 0.354. Combining ITCF with animal type and country dummies improves the forecasting precision of PR predicting models, as the MAFE significantly drops to 0.281 in the model in column (3). Meanwhile, adding the trend variable deteriorates the out-of-sample forecast precision. This is indicated by the increase in the MAFE of models in columns (2) and (4), in comparison with those in columns (1) and (3), respectively. This effect is consistent with the in-sample result that the trend variable has a minor contribution in predicting the PRs.

The statistical significance of differences of models' absolute forecast errors are evaluated using the Diebold-Mariano tests. Their p-values are presented in the left panel of Table 3. With all p-values less than 0.05, we conclude that the absolute forecast errors of all models are significantly different from the others.

Table 3 Diebold-Mariano test results for out-of-sample evaluation

Model	Regression models with dependent variable PR				Regression models with dependent variable log(PR)			
	1	2	3	4	1	2	3	4
1	-	<0.0001	0.006	0.004	-	0.1405	0.0006	0.0003
2	-	-	<0.0032	<0.0001	-	-	0.0032	0.0001
3	-	-	-	0.039	-	-	-	0.1213
4	-	-	-	-	-	-	-	-

Note: This table presents the Diebold-Mariano tests for out-of-sample forecast precision results, with forecasting target as the PR. The test is performed on forecasting error series of model *i* and *j* (*i,j* = 1,...4). The null hypothesis is that model *i* and model *j* have a similar level of accuracy. The alternative hypothesis is two models have different levels of accuracy. With *p-value* <0.05, we reject the null hypothesis. We use – to denote that two models do not require comparison, or the result is repeated and therefore not presented.
Source: Authors´ calculations

5 ROBUSTNESS ANALYSIS

Figure 1 shows the presence of outlying values for the PRs of chicken in Austria and sheep in Greece. Those outlying values may have a large effect on the estimates. As a robustness analysis, we therefore repeat the analysis but with the log(PR) as dependent variable. It can be seen in Figure 2 that the log transformation reduces the extremes.

Table 4 Robustness tests for the log(PR) of processing livestocks

Panel A: In-sample regression estimates

	(1)	(2)	(3)	(4)
ITCF	0.594*** (0.038)	0.586*** (0.037)	0.604*** (0.086)	0.645*** (0.087)
Trend		0.002** (0.001)		–0.002*** (0.0004)

Table 4 (continuation)

Panel A: In-sample regression estimates

	(1)	(2)	(3)	(4)
Chicken			0.261*** (0.056)	0.284*** (0.058)
Pig			–0.079* (0.040)	–0.065 (0.040)
Sheep			0.366*** (0.054)	0.362*** (0.054)
Austria			0.114** (0.040)	0.131*** (0.039)
Belgium			0.115*** (0.029)	0.103*** (0.028)
Czech Republic			0.132*** (0.028)	0.160*** (0.029)
France			–0.130*** (0.022)	–0.155*** (0.024)
Greece			–0.017 (0.029)	–0.010 (0.028)
Italy			0.078** (0.029)	0.059* (0.029)
Luxembourg			0.114*** (0.026)	0.105*** (0.026)
Netherlands			0.023 (0.021)	-0.011 (0.021)
Spain			0.288*** (0.026)	0.302*** (0.026)
UK			0.018 (0.024)	0.006 (0.022)

Table 4 (continuation)

Panel A: In-sample regression estimates

	(1)	(2)	(3)	(4)
Constant	−0.496*** (0.054)	−0.527*** (0.056)	−0.595*** (0.167)	−0.611*** (0.167)
R^2	0.401	0.407	0.762	0.767
Adjusted R^2	0.400	0.405	0.756	0.761

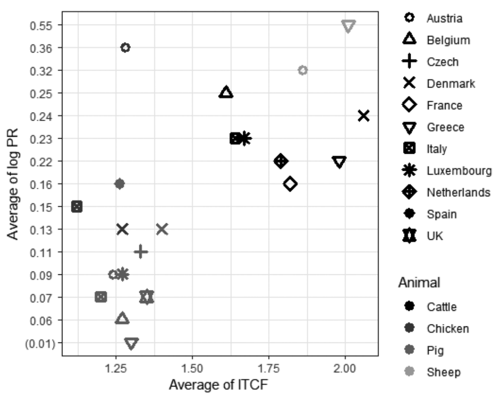
Panel B: Out-of-sample forecast precision results

	(1)	(2)	(3)	(4)
MAFE for forecasting PR	0.348	0.360	0.276	0.270

$*p < 0.1$; $**p < 0.05$; $***p < 0.01$

Note: This table presents results of four regression models (nested in Formula (3)) with dependent variable log(PR) and independent variables ITCF, animal type, and country dummies.
Source: Authors´ calculations

Figure 2 Scatter plots of the average log(PR)s versus the average of ITCFs



Note: This figure displays the average of log(PR)s in relation to the corresponding average ITCFs of 21 sample cases.
Source: Authors´ calculations

The regression model for the log(PR) of animal type a for country c in year t is:

$$\log(PR)_{a,c,t} = \alpha + \alpha_a + \alpha_c + \gamma \text{Trend}_t + \beta \, \text{ITCF}_{a,c,t} + \varepsilon_{a,c,t} \,. \tag{3}$$

Note that the parameter β is now to be interpreted as a semi-elasticity indicating the expected percentage change in the PR when the ITCF increases by 1%. In other words, if the ITCF increases by 1 unit, we can expect the PR to increase on average by 100β%, ceteris paribus.

The results of in-sample tests for regression models of log(PR) with ITCF, animal type, and country are presented in Table 4. We find that the least squares estimates of the slope coefficients of ITCF with log(PR) are stable around 0.6 for all four nested models and statistically significant at the 95% confidence interval. If the ITCF increases from 1 to 2, the price ratio is expected to increase by 60% on average, ceteris paribus. Based on Figure 1, we can see that this effect is smaller than the unit slope coefficient found in the model with PR as the dependent variable. This smaller effect follows from the fact that taking log-transformations of PRs dampens the effect of the vertical outliers for the prices ratios of chicken in Austria and sheep in Greece. In general, we see that the estimations support our conclusions for the main regression models of PR and three independent variables.

In terms of explanatory power, we find that the single-variate model can explain 40.1% of the variation in the log(PR) and that adding animal and country variables substantially increases the goodness of fit. This is demonstrated by the change of R^2 in the model in column (3) of Table 4, from 40.1% to 76.2% compared to the model in column (1). Meanwhile, adding the variable Trend has a minor impact on the good of fitness, as its presence increases only the R^2 with 0.5 percentage points.

In Panel B of Table 4, we report the results of the out-of-sample evaluation of the forecasting precision of PRs using the log(PR)-based prediction models. Here, the single-variate model has the highest MAFE of 0.348, while the model combining all four independent variables has the lowest MAFE of 0.277. To check whether or not the forecasting errors between models are significantly different, the Diebold-Mariano tests are used. The *p*-values in the right panel of Table 3 show that there is no improvement in prediction power of models in the first two columns of Table 4. However, the forecasting errors are significantly lower when we combine three explaining variables: ITCF, animal type, and country. Moreover, even though the model in column (4) has the lowest MAFE, its prediction precision is not significantly better than the model in column (3). As such, among the four models, we recommend model (3) to be the most parsimonious for forecasting the PR. Note that with the same predictors, this preferred model with the log(PR) yields more accurate PR predictions (MAFE of Panel B in Table 2) than the model with the PR as dependent variable (MAFE of Panel B in Table 4). We verified that the forecasting precision is statistically significant at the 95% confidence level.

DISCUSSION AND CONCLUSION

In this paper, we study the TCF and its relation with the PR of processing livestock from live weight meat to carcass meat. Studying this relation is important for two reasons. First, understanding the close relation between the TCF and the PR is important to comprehend the passthrough between the physical efficiency of the processing of livestock and the corresponding PRs. Second, from a statistical perspective, the TCF can be used for imputation when prices are missing.

We proposed a simple model to predict the PR using the TCF, making it feasible to implement the imputation in a setting with a large number of countries and products. Such a large-scale analysis is of great importance for official institutions, as mentioned by Boudt et al. (2009). We concentrate on four major animal types (cattle, chicken, pig, and sheep) and countries belonging to the European CAP. The empirical analysis confirms that there is a statistically and economically significant relation between TCFs

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