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Abstract

The article presents a generalization of an identification scheme of a monopolistic markup proposed by De Loecker and Warzynski (2012). We showed the relation between a price markup and factor wedges arising either due to firm's monopsony power and/or factor adjustment costs. The joint estimation of both kind of wedges (or price markup only) is subject to an identification problem and we discussed the possible restrictions identifying all wedges jointly. We argue that the identification restriction implicitly imposed in the empirical literature is reasonable, but in specific circumstances (or with additional information introduced) different choices may lead to better estimates of not only price markups, but also factor wedges if available data allow to measure multiple variable production factors.

Keywords: markup, wedge, monopsony power, identification

JEL Classification Numbers: D22, D24, D4, J42, L11

Introduction

This article presents a generalization of a identification scheme of a markup of price over marginal cost proposed by De Loecker and Warzynski (2012) (which contributed to a vivid discussion on a development of markups, especially in hte U.S., see De Loecker, Eeckhout, and Unger, 2020). It allows for a joint derivation of a price markup and the extent of firm's monopsony power.

De Loecker and Warzynski (2012) identifiy firm and time varying markups in two steps. First, they estimated a firm level production function using Ackerberg, Caves, and Frazer (2015) and derive the production function elasticities. Second, they utilize a first order condition of firm cost minimization problem to derive a price markup from the ratio of a factor elasticity to a revenue cost share od this factor. However, in order to calculate the markup in the second step one need to choose to which production factor one applies the measurement equation. This choice, as discussed in Syverson (2019) and Basu (2019), is non-trivial and the analyses of Traina (2018) and De Loecker, Eeckhout, and Unger (2020) show it can significantly affect the evolution of aggregate markups. Moreover, this choice implicitly imposes an assumption (which we will discuss later) that the firm has no monopsony power (or no adjustment costs) on the market for this factor.

We propose a generalization of the above identification scheme for markups that additionally allows to derive the measures of monopsony power. The generalization is possible with utilization of additional disaggregated information on production factors. We present the nature of the relation between the price-cost markups and the monopsony power the firm may have on factor markets and discuss an additional identification problem that arises in the methods that build on cost-minimization approaches, like De Loecker and Warzynski (2012). We also present possible identification restrictions needed to pin down both price markup and factor wedges.

*SGH Warsaw School of Economics, e-mail: mgradz@sgh.waw.pl I would like to thank Jakub Growiec and Marcin Kolasa for their valuable comments. One of Marcin's comment actually almost turned my initial findings upside down but finally let me build a more robust and comprehensive argumentation. The views expressed herein belong to me and have not been endorsed by institutions I work for.

The paper closest to ours is Morlacco (2019), but she is identifying the wedge arising due to monopsony power of the buyer using data on import prices. We instead highlight the fact that a firm can have multiple wedges on input markets but it faces only one wedge on output market. It stresses the importance of a product homogeneity assumption.

The rest of the paper is organized as follows. First, we derive the markup measurement equation(s) with three set of assumptions: without monopsony power/adjustment costs, with monopsony power and with the introduction of adjustment costs. Then we present the set of equations that allow to jointly estimate monopoly and monopsony markups. In the next section we discuss the possible restrictions that allow to joint identification of both kind of wedges. The last section concludes.

1 Identification of markups

1.1 Monopoly power

The identification of a markup proposed by De Loecker and Warzynski (2012) builds on a static cost minimization problem. Let the production function of a firm i in period t producing a homogeneous product Q_{it} is:

$$Q(\Omega_{it}, \boldsymbol{V_{it}}, K_{it}) = \Omega_{it} F_t(\boldsymbol{V_{it}}, K_{it}), \tag{1}$$

where Ω_{it} is a Hicks-neutral productivity, K_{it} is a stock of capital (inherited from the previous period) and $\boldsymbol{V_{it}}$ is a set of j inputs free to adjust in period t (e.g. labor). The Lagrangian associated with the cost minimization problem is:

$$\mathcal{L}(\boldsymbol{V_{it}}, K_{it}, \Lambda_{it}) = \sum_j P_{it}^j V_{it}^j + r_{it} K_{it} - \Lambda_{it} \left(Q \left(\Omega_{it}, \boldsymbol{V_{it}}, K_{it} \right) - Q_{it} \right), \tag{2}$$

where Λ_{it} is a Lagrange multiplier associated with output – a measure of marginal cost.[1] The FOC with respect to any variable input j can be rearranged as:

$$\frac{\partial Q(\cdot)}{\partial V_{it}^j} \frac{V_{it}^j}{Q_{it}} = \frac{1}{\Lambda_{it}} \frac{P_{it}^j V_{it}^j}{Q_{it}}. \tag{3}$$

Let us define the production function elasticity to a factor j as $\theta_{it}^j \equiv \frac{\partial Q(\cdot)}{\partial V_{it}^j} \frac{V_{it}^j}{Q_{it}}$ and the markup μ_{it} as a price over marginal cost $\mu_{it} \equiv \frac{P_{it}}{\Lambda_{it}}$. Rearranging (3) we can get:

$$\mu_{it} = \theta_{it}^j \left(\frac{P_{it}^j V_{it}^j}{P_{it} Q_{it}} \right)^{-1}. \tag{4}$$

It follows that the markup μ_{it} of price over marginal cost can be measured by the distance of elasticity of production to a factor θ_{it}^j (revenues generated by this production factor) to a revenue share of costs associated with this production factor.

1.2 Monopoly and monopsony power

Consider the case when a firm has additionally monopsony power in markets for variable factors. Then the price of an input depends on firm's quantity demanded and the Lagrangian associated with a firm's cost minimization becomes:

$$\mathcal{L}(\boldsymbol{V_{it}}, K_{it}, \Lambda_{it}) = \sum_j P_{it}^j (V_{it}^j) V_{it}^j + r_{it} K_{it} - \Lambda_{it} (Q(\cdot) - Q_{it}), \tag{5}$$

with a FOC for a factor V^j:

[1] As in equilibrium with a binding production constraint $\Lambda_{it} = \frac{\partial TC_{it}}{\partial Q_{it}}$, where $TC_{it} = \sum_j P_{it}^j V_{it}^j + r_{it} K_{it}$

$$\frac{\partial P_{it}^j(V_{it}^j)}{\partial V_{it}^j} V_{it}^j + P_{it}^j = \Lambda_{it} \frac{\partial Q(\cdot)}{\partial V_{it}^j}. \tag{6}$$

When we define a (gross) elasticity of input j's price to quantity demanded (the measure of monopsony power) $\eta_{it}^j \equiv 1 + \frac{\partial P_{it}^j(V_{it}^j)}{\partial V_{it}^j} \frac{V_{it}^j}{P_{it}^j}$ and use the same definition of markup as before the equation (6) can be rearranged as:

$$\mu_{it} \eta_{it}^j = \theta_{it}^j \left(\frac{P_{it}^j V_{it}^j}{P_{it} Q_{it}} \right)^{-1}. \tag{7}$$

Equation (7) shows when a firm has a monopsony power on a market for input j, then the same measure as in (4) $\theta_{it}^j \left(\frac{P_{it}^j V_{it}^j}{P_{it} Q_{it}} \right)^{-1}$ contains information on both monopoly power μ_{it} and monopsony power η_{it}^j. Importantly, the extent of the monopsony power can differ across factors V_j (encompassing the case with no monopsony power $\eta_{it}^j = 1$) whereas under homogeneity of the final product a price markup μ_{it} is the same across a set of j equations in (7).

1.3 Monopoly power and adjustments costs

Consider now the case when a firm face adjustment costs[2] in the variable production factor(s) of a general form $\Phi_j(V_{it}^j)$. Then the Lagrangian associated with cost minimization becomes:

$$\mathcal{L}(\boldsymbol{V_{it}}, K_{it}, \Lambda_{it}) = \sum_j P_{it}^j V_{it}^j + r_{it} K_{it} + \sum_j \Phi_j(V_{it}^j) - \Lambda_{it} \left(Q(\cdot) - Q_{it} \right). \tag{8}$$

When we define the elasticity of adjustment cost $\phi_{it}^j \equiv \frac{\partial \Phi_j(V_{it}^j)}{\partial V_{it}^j} \frac{V_{it}^j}{\Phi_j}$ then the FOC associated with factor V_j becomes:

$$\mu_{it} \left(1 + \phi_{it}^j \frac{\Phi_j(V_{it}^j)}{P_{it}^j V_{it}^j} \right) = \theta_{it}^j \left(\frac{P_{it}^j V_{it}^j}{P_{it} Q_{it}} \right)^{-1}. \tag{9}$$

When we define $\tilde{\eta}_{it}^j = 1 + \phi_{it}^j \frac{\Phi^j(V_{it}^j)}{P_{it}^j V_{it}^j}$ as a (gross) weighted adjustment cost elasticity then equation (9) takes the form:

$$\mu_{it} \tilde{\eta}_{it}^j = \theta_{it}^j \left(\frac{P_{it}^j V_{it}^j}{P_{it} Q_{it}} \right)^{-1}. \tag{10}$$

and clearly shows that the ratio of output elasticity to factor share contains a mixture of information on both markups and adjustment cost elasticity.

It can be easily shown that when we assume both monopsony power and adjustment costs then the equation (10) is unaltered, but $\tilde{\eta}_{it}^j$ becomes $\tilde{\eta}_{it}^j = 1 + \eta_{it}^j + \phi_{it}^j \frac{\Phi^j(V_{it}^j)}{P_{it}^j V_{it}^j}$, so $\tilde{\eta}^j$ is not a pure measure of monopsony power.

2 Joint identification of price and monopsony/adjustment costs markups

The above derivations show that the ratio of a production function elasticity and the revenue cost share contains information on price markups μ_{it}, but the markups are directly identified only if

[2]The problem we describe is static and adjustment costs usually arise in dynamic settings. One may treat adjustment costs in our approach as an reduced form of dynamics in a firm's decision, which is absent here. The derivation of identifying equations for wedges in a dynamic decision model is out of the scope of the paper.

there are no adjustment costs[3] and/or monopsony power. If instead, a firm's demand for a factor affects its price or triggers additional adjustment costs, then the ratio of a factor elasticity and a revenue factor share is composed of two wedges — the markup of price over marginal cost μ_{it} and the wedge associated with changing the quantity of a factor, either due to monopsony power (η^j_{it}) or due to adjustment costs ($\tilde{\eta}^j_{it}$), or both. It introduces the bias in the measurement of price-cost markups. It is worth noting that without additional information on the structure of the market for factors or independent measurement of adjustment costs, $\tilde{\eta}^j_{it}$ is observationally equivalent to η^j_{it}.

With monopsony power and/or adjustment costs the measurement equation (10) in logs takes the form:

$$\log \theta^j_{it} - \log \left(\frac{P^j_{it} V^j_{it}}{P_{it} Q_{it}} \right) = \log \mu_{it} + \log \tilde{\eta}^j_{it}. \tag{11}$$

As there are j variable factors of production and the equation holds for every free-to-adjust factor it is actually a system of j equations with $j+1$ variables (a j-dimensional vector of $\log \tilde{\eta}^j_{it}$ and a scalar $\log \mu_{it}$).[4] A solution to a set of equations (11) has a specific nature — μ_{it} is factor-independent (as it applies to a homogeneous output) whereas $\tilde{\eta}^j_{it}$ are factor-specific (as we allow for many production factors, each with a potential wedge). In order to solve the system one additional identifying restriction is necessary.

3 Discussion of identification restrictions

There are many ways to identify equations (11). Below we discuss some of the possible restrictions and relate them to the existing literature, but in empirical settings one should choose the one that is economically and empirically valid. Table 1 presents a simple illustrating example for a firm with capital and $j = 3$ variable inputs (labor, energy and materials). The first and the second column present production function elasticities θ^j and revenue factor shares for each input. The log difference between the two is calculated in the third column. The numbers are typical and close to respective averages in empirical settings. Notice (in the summation row) that in general production function need not to have constant returns. Moreover, with non-zero profit rate (here it is 6%) the revenue factor shares do not sum to one. The last four columns of the table present the solution to (11) with different identification restriction, discussed below.

Table 1: An example application of various markup identification schemes

factor j	θ^j	$\frac{P^j V^j}{PQ}$	log(ratio)	factor markup $\log \tilde{\eta}^j$ (1)	(2)	(3)	(4)
capital	0.18	0.18					
labor	0.35	0.34	0.029	-0.049	-0.067	-0.029	0.000
energy	0.06	0.05	0.182	0.104	0.086	0.124	0.153
materials	0.40	0.37	0.078	0.000	-0.018	0.020	0.049
$\sum_j x_j$	0.99	0.94					
$\log \mu$				0.078	0.096	0.058	0.029
μ				1.081	1.101	1.060	1.029

We start with the restriction that is implicitly imposed by De Loecker, Eeckhout, and Unger (2020) and is used commonly in recent empirical literature, which is to choose materials (COGS - cost of goods sold, or both COGS and SG&A, selling, general and administrative expenses, as in

[3]The equation (9) can be also expressed as: $\mu_{it} = \theta^j_{it} \left(\frac{P^j_{it} V^j_{it} + \phi^j_{it} \Phi^j(V_{it})}{P_{it} Q_{it}} \right)^{-1}$. Thus, if the available data allows to measure all costs associated with factor changes, including adjustment costs and to calculate the revenue factor cost share properly, then one can directly identify a markup μ_{it}.

[4]The *it* subscript means in the empirical settings that a set of equations (11) applies to each firm-period observation.

Traina, 2018) as a baseline variable production factor.[5] This choice is equivalent to a restriction that $\tilde{\eta}^j_{it} = 0$ for this input, which corresponds to column (1) in the middle of table 1. Of course this restriction pins down the markup μ_{it} (here at 8.1%) but we argue that as long as the available data allows to measure separately different variable factor costs, it also pins down the factor wedges for all variable inputs. The economic rationale for this restriction is well motivated — materials correspond usually to a bundle of different components and even large firms rarely have monopsony power on all these markets. Moreover, with fluctuating production it is common that firms frequently adjust its demand for materials (it is common to assume in the literature that the elasticity of substitution between materials and value added is close to zero and estimates in Atalay, 2017, shows that it is indeed the case), which suggest that the adjustment costs seem to be rather minor. On the other hand, firms in the longer term may change the way they operationally use materials in the production process, which may affect the long-term trends in markups. Examples include the introduction of so called lean production or the emergence of Global Value Chains with accompanying fragmentation of production and resulting changes in the structure of inputs used.[6]

The second identification possibility stems from the structure of a set of equations (11) — it decomposes the log distance between a production function elasticity and a factor revenue share into a price markup that is common to all factors and factor-specific wedges. Therefore, it is possible to utilize the fact that $j > 1$ and to regress $\log \theta^j_{it} - \log\left(\frac{P^j_{it} V^j_{it}}{P_{it} Q_{it}}\right)$ on a constant, or equivalently to calculate its mean (over j), both giving an estimate of $\log \mu_{it}$. The realizations of the error term correspond in this case to factor wedges. The example calculations corresponding to this case are presented in the column (2) in Table 1. This identification scheme seems to be very good one, but it assumes that $\sum_j \tilde{\eta}^j_{it} = 0$. It follows that it must be the case that at least one factor wedge is negative. Moreover, if the true $\sum_j \tilde{\eta}^j_{it} \neq 0$ then the estimate of μ_{it} is (most probably upward) biased.

Third, one may use outside information to pin down one of the unknown variables. If factor wedges are of the primary interest, one may use the Learner's Index to pin down the markup and solve (11) for these wedges. This identification scheme is presented as column (3) of Table 1, where the price markup was set at 6%. Morlacco (2019) proposed another interesting way to assure identification adding more information (on relative prices of imported inputs) into the system.

Fourth, one may argue that a firm have no monopsony power for a different production factor and there are minimal additional costs associated with adjusting the employment of this factor. The column (4) of Table 1 presents labor as an example of such a factor. When searching for economic arguments for a given identification scheme one may follow Basu (2019) who suggests it is safer to use a more comprehensive input as a base to markup measurement. This intuition is well motivated as the markup is determined by the ratio, not the difference between the elasticity and the factor revenue cost share. Therefore, even small divergence between the two for factors with small cost share translates into large markup estimates (and variation), as can be seen when comparing 'log ratio' column for the labor and energy (both with 1 pp. difference between θ^j_{it} and factor revenue cost share) in table 1.

Moreover, there are many other ways to identify (11). In practical applications one may set to zero the wedge for the factor with the smallest log difference between the elasticity and the corresponding revenue cost share (in the case of our example it corresponds to column (4) in Table 1). The derivation of the markup relies on the static cost minimization but in practice it is commonly used in a panel of firms. In order to avoid the unwanted variation in the resulting wedge estimates the identification strategy should be time-invariant or common across similar group of firms. In practice the choice is frequently restricted by the detail level of available data.

[5] De Loecker and Warzynski (2012) discusses the differences of choosing materials and labor in the context of value added versus gross output production function and adjustment costs.

[6] It was the reason why Gradzewicz and Mućk (2019) decided to take labor as a baseline factor

Conclusions

In this article we presented a generalization of a identification scheme of a markup of price over marginal cost proposed by De Loecker and Warzynski (2012). We showed the relation between the markup of price over marginal costs and factor wedges arising either due to firm's monopsony power and/or factor adjustment costs. In order to solve the resulting set of equations jointly for markups and factor wedges one need to impose one identifying restriction. What is more important, the identification problem is also present when one focuses on monopolistic markups only, as in De Loecker, Eeckhout, and Unger (2020). We discussed the possible identifying restrictions, including the one that is implicitly assumed in the empirical literature. We argued this assumption is reasonable, but in specific circumstances (or with additional information introduced) different choices may lead to better estimates of both markups and factor wedges. We also stressed that the ability to better pin down the markup estimates stems from the utilization of more disaggregated information on production factors, which is subject to data constraints. We decided to focus here on the theory behind the identification of markup, leaving the practical application and assessing the significance of our argument for further research.

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