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Distributed Use Models to Expand Small Batch Manufacturing Flexibility

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Abstract*: *Small-batch manufacturing flexibility and agility are addressed with regard to operational possibilities to maintain financial stability and keep-up with the value creation in case of the market's positive fluctuations: excessive demand which can be responded by output expansion. If a small-batch manufacturer faces capacity constraints, traditional patterns to invest in fixed assets can be value-consuming thus leaving many manufacturers aside from the competitive market opportunities. We argue that the sharing economy phenomenon can contribute to the problem resolution. To prove our hypothesis, we distinguish between sharing and other known outsourcing-based models of production, determine the key factors that influence decision-making and decompose a business valuation model to enable simulation modeling of value response to sharing-based practices introduction. Our finding indicate that sharing can be treated as "on-call" employment of an outsource supplier's underutilized production capacity that leads to revenue growth followed by value factors proportional and non-proportional changes. The imitation model shows that sharing-driven output expansion provides a four-percent increase of business value in the assumed conditions; the traditional approach to support the growing demand with fixed assets expansion can be effective only in the long-term perspective given the new level of sales will be maintained without a subsequent rollback. Further increase of the model precision can be achieved by employing the survey-based estimates of a business's individual extent of sharing perception.

Keywords*: *Small Batch Manufacturing, Sharing Economy, Enterprise Value, Flexibility, Smart Contract, Co-Management.

I. INTRODUCTION

Small batch manufacturers face significant challenges in their competition for market shares and niches. They face a lot of constraints including those from the market, macroeconomic policy, resource supply, capital availability and affordability, as well as from the technological side of their operations. Theoretically, small batch manufacturers can faster respond to changing market demand due to their assumed flexibility in product customization, but they are rather limited in ability to provide the necessary extra amount of goods and services to their current and potential customers if the quantity expansion is required promptly.

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A proper comparison of business processes of small-batch and mass manufacturing enterprises is provided by Chao (2012), who studied the factors influencing their production efficiency and constructed productivity promotion model considering customer development, product design, production, processing and material supply to increase performance [1]. Compared to the big manufacturers, the small-batch ones can be more responsive to the market demand changes only if they have appropriate capital resources or an excess production capacity. That is why funds accessibility can be crucial if a company's competitiveness is determined by its ability to rescale the output.

In Carr (2018) we find a proper explanation of competitiveness driven by flexibility which is presumably attributable to small batch manufacturers: "custom-made products for smaller niche markets are available and accessible with just the click of a mouse or tap on a screen. That raises consumers' expectations for getting exactly what they want, when they want it… This creates new business opportunities for manufacturers that can deliver the goods"[2]. If a manufacturer can promptly revise the output plans and implement the amendments it will highly likely succeed in positively responding to market challenges to absorb the new value added. In short, manufacturing flexibility is the ability of a plant to produce small batches and customized items.

But another thing to mention is the average duration of higher demand which makes the roll-back expenditure a crucial aspect to account for. Excess market demand can be a short-term possibility for a company, followed by a downslope of sales afterwards. If a company follows traditional pattern to purchase fixed assets, it will face the cash outflow that will not be recovered by excess sales. Cash or credit purchases and leases can be done rapidly only in theory and are usually not considered as a type of short-term intervention; when impact of the demand growth gets depleted it will be necessary to minimize the assets' related cost of ownership, otherwise such an immobilization of cash in the long-term perspective can be economically irrational due to liquidity-vs-profitability issues that undermine business value.

Searching through the literature reveals another important concept of an enterprise's flexibility – agility, which is physically meant to be the ability to change the direction of a physical object in an efficient and effective manner under different external influences or shocks achieved by a combination of static and dynamic balance, speed, strength and coordination.

Business agility is a firm's capability to respond to unexpected environmental changes using available resources. According to Leybourne, agility is interpreted as the "ability of a business system to rapidly respond to change by adapting its initial stable configuration" [3].

Hamel and Välikangas assume that the agile enterprise strives to make change a routine part of organizational life to reduce or eliminate the organizational trauma that paralyzes many businesses attempting to adapt to new markets and environments [4].

To rearrange, under pressure of the permanent change, an agile enterprise can quickly adjust and take advantage of emerging opportunities as well. This implies a manufacturer to have the capacity to provide an additional or diverse output accompanied by the managerial preparedness to react in response to change. In the context of the problem in scope, an agile manufacturer is the one whose output can fluctuate synchronously with the market without major opportunity cost and transaction cost as well.

Agility is often synonymized with corporate resilience defined as the ability of a system to withstand changes in its environment and still function. But, to our knowledge, the common perception of the broad category of risk tents to admit its "negative" connotation: the change is meant to be a negatively influencing factor, agility and resilience are considered to enable a company's recovery from stress or shock – to get back to some level of normality. Yet, risk is a two-ways phenomenon, at least mathematically (square root of SD), and being not able to meet the potential change to good is also a problem in terms of the current and future competitiveness. We argue that change to good must be met preparedly and introduce the new theoretical concept of "FlexiGility" which is an ability to quickly respond to the market demand changes and to recover afterwards without major expenditure. It is the composition of "resilience – agility – flexibility" trio. This match could be a very good sort of competitive advantage, and flexibility itself might become a core competency for any company that produced commodities.

The described technical and financial constraints keep small batch manufacturers off the perfect match of flexibility and agility: they can be flexible in terms of quality, but quantity challenges can hardly be responded promptly. From the business practices we know several approaches to follow the market expansion signals and respond to them accordingly. The major strategies include subcontracting, outsourcing, own capacity expansion (through investment) and some modern phenomena based on collaborative consumption.

Undoubtedly, many manufacturers use subcontracting and outsourcing to avoid investment in expensive equipment: insufficient capital is a common resource shortage, and, via subcontracting companies are able to quickly increase their output without incurring additional capital investment [5]. A special case of subcontracting is a "professional" outsourcer company whose core competency is to be well-prepared to variability of output, volatility of batches, complicatedness of logistics or to excessive customization of products. This concept fits into the Production as a Service (PaaS) framework that connects **product** developers who have small batch production needs, with existing manufacturing facilities that have **underutilized resources** [6].

According to Balta et al. (2018), PaaS is a framework based on the service-oriented architecture design that breaks down the manufacturing of a product into several steps, or services, to incorporate various manufacturers with available capability in fulfilling the production request subject to economic effect maximization.

An important issue of technology access and preservation is also emphasized in the literature. On the one hand, small batch manufacturers that use PaaS face risks of intellectual property rights violation (e.g., see Balta et al. [6]), especially if the outsourcer is in a foreign jurisdiction. On the other hand, Pardo and Rama argue that "subcontracting of production do not lower necessarily the technology needs.

Networking itself is not likely to allow access to new technology" [5]. The latter argument is a reasonable critique to the networking-panacea apologists. Both subcontracting and outsourcing practices indicate that a proper solution might come from network effects that are widely described in the literature. One of the phenomena relative to the network effects is collaborative consumption supplemented by collaborative assets employment.

According to Möhlmann, collaborative consumption takes place in organized systems or networks, in which participants conduct sharing activities in the form of renting, lending, trading, bartering, and swapping of goods, services, transportation solutions, space, or money [7]. Surveys say that companies can benefit from the network density increase and vice versa [8] if business activity in some market or segment is becoming more intense. Thus, theoretically, the network effects provide nonlinear increases of the total market performance, thus influencing the economic value added of the manufacturers. The research objective is to provide the rationale for the network effects employment under the sharing economy concept implementation to enable small batch manufacturers' "flexigility", and to introduce the generalized financial model to estimate business value change under the influence of sharing economy principles introduction. We assume that flexigility achievement is best possible within the networking framework: network effects and collaborative consumption supplemented by collaborative assets employment can increase overall business value. Collaborative consumption phenomenon is converged to the sharing economy concept. Our research is intended to contribute to the scientific fundamentals of sharing practices and to answer the question if sharing expansion is anticipated and can contribute to business value increase within the network-style organization of business transactions.

II. THEORY

The sharing economy (or distributed use economy) has been growing exponentially during the recent years. Some theorists explained that growth as the response to crises and uncertainty, or as an instrumental strategy to cut manufacturing costs.

Yet, the vast practical background and numerous theoretical explanations allow to conclude that sharing has become a standalone economic and financial phenomenon significantly changing the economic landscape and several fundamental principles of production such as a factor dependency of value on assets' possession, use or ability to dispose. Long-term ownership over fixed assets has been considered as a factor of an enterprise's competitiveness and financial resilience, a driver of capitalization growth. Nevertheless, it became clear that long-term possession of fixed assets can be considered as a competitive advantage only in case of their liquidity or uniqueness, otherwise possessing an asset implies a tradeoff between costs of ownership and risks of inability to use the asset.

Does it mean that sharing economy can contribute resolving the ownership inequality? According to L. Richardson, it does not: "the sharing economy simultaneously masks new forms of inequality and polarizations of ownership". She concludes that "sharing economy constitutes an apparent paradox, framed as both part of the capitalist economy and as an alternative. This duplicity necessitates focusing on the performances of the sharing economy: how it simultaneously constructs diverse economic activities whilst also inviting the deconstruction of ongoing practices of dominance" [9]. C.J. Martin (2016) goes deeper and states that sharing economy's destructive potential is expanded to creating unregulated marketplaces, reinforcing the neoliberal paradigm and developing an incoherent field of innovation [10].

Yet, Puschmann and Alt (2016) describe numerous positive effects of sharing economy that include capital saving effects, consumer convenience, ecological, reputational, social and several other benefits of sharing [11]. They also indicate business opportunities for the current and potential intermediaries that contribute to the general employment by providing additional value added. H. Heinrichs (2013) adds that the "sharing economy" has the potential to provide a new pathway to sustainability [12]. C.J. Martin develops it arguing that sharing economy is an economic opportunity, a more sustainable form of consumption and a pathway to a decentralized, equitable and sustainable economy [10].

From the technical implementation point of view, sharing can be identified as the specific type of "on-call" rentals which is based on the principle of unconditional consent of a lessor to have a contract. Sharing as an economic phenomenon goes further compared to a straightforward way of transferring an object or an asset to a user for temporary employment. The modern connotations of sharing assume transfer of functions and business-processes under sharing agreement. This transfer is handled by an intellectual dispatching system which is generally perceived as "Uberization". The latter is driven and empowered by technological platforms of multi-user interaction that "have simplified sharing of both physical and nonphysical goods and services through the availability of various information systems on the Internet" [13].

Such an interaction provides costs minimization at the majority of operating income formation levels, including minimization of the expenditure burden held by an assets' title owner. Thus, theoretically and rationally the sharing economy as a phenomenon can potentially facilitate business value growth, both for a separate company or a business sector in general. Notably the research papers published by now mostly contain only the general conceptualization of sharing as well as the first attempts to describe the practical approaches to evaluate its impact on performance and efficiency of enterprises.

According to the definition proposed by STOXX, sharing is an economic model that is based on acquiring, providing or sharing access to goods and services via community-based platforms. The shared resources are reusable and required for a temporary use, leading to extensive and productive use of underutilized resources"[14].

We suggest that sharing is an asset-on-demand approach to organize the production that employs intellectual capital from inside and physical capital from outside of the company. Our definition of sharing requires an explanation. The comprehensive case of car-sharing gives us a proper practical background to implement PaaS methodology.

Each product consists of a combination of the four general factors:

- "F" – fixed asset (property, plant and equipment),
- "W" – working capital (raw materials, energy, etc.),
- "C" – competency (product design and technology, intellectual property rights protection, workforce, including administrators and implementors);
- "M" – market (group of current and potential consumers, distribution channels, etc.).

Except for the "M", factors can migrate between holders / owners. Thus, the following combinations are possible (see Table I):

Table- I: Variants of small-batch manufacturing models

M	Factors	C			W	F
	Components	***Product Design***	***Technology, know-how***	***People***	***Resources***	***Machinery***
1	In-House manufacturer	1[a]	1	1	1	1
2	Outstaffing user	1	1	0	1	1
3	Sharing user	1	1	1	0	0
4	Outsourcing user	1	0/1	0	0	0
5	Contracting user	0	0	0	0	0
6	Outsourcing provider	0	0/1	1	1	1
7	Sharing provider	0	0/1	0	1	1

a. "0" – component is absent, "1" component is present.

III. METHODOLOGY

Following Cheng [15] and Frenken & Schor, who tried to analytically conceptualize and empirically assess the various impacts of the current sharing economy platforms in terms of people, planet and prosperity [16], we address the problem of quantity estimates of the sharing economy potential influence on economic performance. To do that, we need to distinguish between sharing and other modes of third-party manufacturing, as well as to introduce the economic performance metrics.

In order to prove the assumed efficiency of sharing in terms of value creation in response to the temporary or prolonged market demand expansion we need to measure the value contribution of competency and to formalize the value dependence on demand expansion under alternative production modes.

We see that under sharing the competency is held by the manufacturer while F and W are outsourced. This can be valuable regarding the above-mentioned critique on the access to technology and intellectual property rights protection. In terms of economic dimension of sharing we can use a very simple way to illustrate the economic benefits of it through the factor value. To do this we compare the cost of product labelled as “office-to-airport travel”. As for the 30th of April 2019, Uber’s charge was 1000 rubles, while Delimobil (Moscow based car-sharing service) travel was 450 rubles. Since roughly the same utility is being purchased, we can present it in the following manner:

$$F_U + W_U + C_U = F_D + W_D \quad (1)$$

Assume transaction costs, car depreciation and fuel consumption are equal in the two scenarios. Then

$$(F_U + W_U) = (F_D + W_D) = 450 \text{ rubles} \quad (2)$$

Consequently,

$$C_U = C_D = 1000 – (F_U + W_U) = 550 \text{ rubles} \quad (3)$$

Since “C” is the most expensive component of a product (in our example) it is rational not to buy it from the outsourcer considering our past investment in competency (e.g., obtaining driving skills and qualifying for driver’s license), even if there is no risk of technology leak.

The employed generalization of the given example, of course, can hardly be applied to all the products, thus a more detailed representation is needed to distinguish benefits of owning / sharing “intellectual” and “physical” assets.

To assess the value changing potential of sharing, it is necessary to run the imitation modeling and test the value changes under the five scenarios below:

- Type 1: excess demand in the market, supported by inhouse production capacity.
- Type 2: excess demand in the market, not supported by inhouse production capacity, investment extended to follow the growth.
- Type 3: excess demand in the market, not supported by inhouse production capacity, sharing employed to follow the growth.
- Type 4: stable demand in the market, sharing employed to decrease costs.
- Type 5: excess demand in the market together with excess inhouse production capacity, sharing provided to other manufacturers.

Enterprise value is a complex category, still there is a uniform approach to measure it. To do that we use a general valuation model where the free cash flow of an enterprise (numerator) is discounted by its cost of capital (divider):

$$V = \frac{(R - K - A)(1 - t) - I + A - W}{(k_d D + k_e E)/(D + E)} \quad (4)$$

Where

R – revenue; R=*f*(Quantity; Price);

K – cost of revenue; K=*f*(R); if ΔR=R*(1+x) – R => ΔK=K*(1+y) – K, x>y;

A – amortization; A=0 for M(3, 4, 5), A>0 for M(1, 2, 6, 7);

t – tax rate, considered constant;

I – investment in fixed assets; ΔI/I = ΔA/A;

W – investment in working capital;

D – value of debt, D≥0;

E – value of equity, E>0; (D+E) = *f*(R);

k_d – cost of debt;

k_e – cost of equity, $k_d < k_e$.

The quantity increase in case of in-house manufacture will activate the operating leverage effect thus the increase of costs will be nonproportional in case of in-house production as well as with all the models that bring production outside. Since any output expansion requires investment in working capital, even though to the different extent, depending on the working capital policy of a given manufacturer and several externalities similarly attributable to all the actors. Hence, market demand expansion will equally influence working capital requirements no matter what manufacturing mode is used.

In case of full utilization of production capacity, an in-house manufacturer will need to invest in plant and machinery that will cause investment in fixed assets growth followed by depreciation increase (cost of ownership) and by a change in total capital due to expansion of debt or equity. The latter will cause changes of capital structure and weighted average cost of capital change. We also assume that price is not affected by demand fluctuations, so the revenue remains the function of quantity only.

We used the Monte Carlo simulation to measure the cumulative effect of sharing models’ use following the model (4) described above. To simulate, we obtained response parameters form the revenue change impact on value components regression results. The regression sample contained 57 Russian manufacturers from 6 industries.

The following assumptions were made prior to simulation modeling:

- a company uses 100% of its production capacity, that is, a response to the demand expansion is possible only through investment in fixed assets or through the use of an outsource supplier capacity (sharing, other options for contracting are not considered);

- the choice between sharing and inhouse production is random (expressed as the dummy $\alpha = 0$ for sharing and $\alpha = 1$ for inhouse production);
- the cost of sales for $\alpha = 1$ relates to the revenue as

$$C = B_C R, \quad (5)$$

where B_C is a regression coefficient of C's percentage change in response to 1% change in revenue; for $\alpha = 0$, we expect an additional cost increase of 10-50% due to greater transaction costs attributable to sharing (direct costs, except labor, will be higher);

- for $\alpha = 1$ (inhouse production) fixed assets investments increase proportionally to revenue growth with a leverage of 101-110%. Greater investment is assumed to be planned since the production capacity is depleted (see the inputs);
- investment in working capital is growing in proportion to revenue growth;
- for $\alpha = 1$ depreciation will be expressed as

$$A = B_A R, \quad (6)$$

where B_A is a regression coefficient of A's percentage change in response to 1% change in revenue;

- for $\alpha = 0$ depreciation growth rate is 0 (when sharing, investments in fixed assets are not expected);
- investments in fixed assets are financed by the growth of debt or equity in proportion to the regression coefficient; for $\alpha = 1$ a pair of dummies is employed: expansion of debt ($\beta = 1$, otherwise 0), expansion of equity ($\gamma = 1$, otherwise 0);
- the cost of capital is assumed unchanged;
- demand impulse (as revenue growth) is planned within 100.01% – 111% interval (expert estimate);
- α, β and γ are normally distributed random values, β and γ are in counterphase to each other;

As a result, we obtain three possible combinations of dummies $\{\alpha, \beta, \gamma\}$ employed in our simulation model:

- {1,0,1} – inhouse capacity expansion through debt increase;
- {1,1,0} – inhouse capacity expansion through equity increase;
- {0,0,0} – use of sharing.

Since this simulation model was built to test a theoretical hypothesis, and not a practical result, the validity was controlled by scaling the number of iterations: 2000, 5000, 15000, 100000 iterations, as well as by reproducing the model on other companies' inputs.

IV. RESULT AND DISCUSSION

To quantify the response of value components to revenue change we took a panel of 57 Russian manufacturers and regressed average growth rates of value components by the average revenue growth.

Table- II: Regression coefficients of value components' dependency on revenue change

	B	p-level
C	0,809859	0,000000***
A	0,173998	0,421111
I	0,48340	0,197242*
D	0,56600	0,071233**
E	0,305015	0,041606***

The characteristics of the regression coefficients indicate a high reliable dependence of cost on revenue, which is natural. Also, statistically significant are the dependencies of changes in capital and investments in fixed assets, while depreciation naturally shows an unreliable dependence on changes in revenue, because not directly related to sales changes. For the purpose of constructing a simulation model, an assumption is made about the validity of the obtained regression coefficients.

An example of a simulation (several iterations) is presented in Table 1.

Table- III: Value and components of a small-batch manufacturer's business value at various iterations

	Initial	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5	Iteration 6
Value	11,216	12,218	11,572	11,829	11,240	11,630	10,806
FCF	1,839	1,994	1,897	1,939	1,848	1,906	1,777
WACC @Kd=8,5; ke=18,6	0,164	0,163	0,164	0,164	0,164	0,164	0,164
R	6,546	7,023	6,781	6,966	7,135	6,788	7,240
C	2,305	2,441	2,455	2,578	2,473	2,450	2,503
A	0,613	0,621	0,613	0,613	0,623	0,613	0,624
I	-1,406	-1,505	-1,406	-1,406	-1,711	-1,406	-1,838
W	-0,271	-0,291	-0,281	-0,289	-0,296	-0,281	-0,300
D	3,267	3,401	3,267	3,267	3,267	3,267	3,267

E	11,629	11,629	11,629	11,629	11,948	11,629	12,005
R growth	-	7,28	3,59	6,42	9,00	3,70	10,61
C growth	-	5,89	6,51	11,84	7,28	6,28	8,58
A growth	-	1,27	0,00	0,00	1,57	0,00	1,85
I growth	-	7,03	0,00	0,00	21,73	0,00	30,74
W growth	-	7,28	3,59	6,42	9,00	3,70	10,61
D growth	-	4,12	0,00	0,00	0,00	0,00	0,00
E growth	-	0,00	0,00	0,00	2,74	0,00	3,23
α-dummy	-	1	0	0	1	0	1
β-dummy	-	1	0	0	0	0	0
γ-dummy	-	0	1	1	1	1	1

The average Monte Carlo simulation result allowed to establish that the response of enterprises to short-term demand growth using sharing-based models provides an increase in business value by an average of 4.4%, while fixed investment, with given parameters, erodes the value by an average of 0.9%.

Table- II: Results of imitation modeling

	Average	**Probability of value decline**
Total growth	1.94	-
Inhouse growth	-0,84	49.6%
Sharing growth	4,37	0.0%

The zero probability of value decrease under sharing model is probably due to the peculiarities of the model specification. Model refinement will become possible after a sample survey of small-batch manufacturers' business models.

The result is reproduced on similar simulations using the initial values of various companies out of 57 included in the panel, which allows to conclude with the described assumptions that the sharing model of production in small batch has a potential of development.

V. CONCLUSION AND FUTURE SCOPE

Sharing is a standalone model of small-batch manufacturing flexibility. The imitation model allowed to prove that sharing-enabled flexibility (ability to positively respond to local increases of demand) provides significant growth of a business value compared to fixed assets expansion.

We proved that small-batch flexibility and agility provided by sharing (the ability to support the excess market demand) can effectively increase value of a business and not to lose it when demand is pacing down to initial normal level.

In further studies, it is necessary to introduce more variable indicators of flexibility and link them as a separate measure of the effectiveness of companies with business value. To do that, it is necessary to design and conduct an interview-based study of specific companies in order to assess the degree of their susceptibility to sharing, taking into account their industry, capitalization, features of the product range, markets and distribution channels, consumer properties of the product, etc. It is a matter of research if manufacturers are ready or not ready to implement sharing in their business models, what constraints are seen by business executives and owners, what can affect decisions made, how much available production potential (under) is loaded and how frequent and significant are the jumps in demand, to take measures to satisfy him.

Further complication of the model can go along the path of decomposition of elements of the production process, as was done by Kong and Jia: the equipment shutdown frequency, parts' handling times, handling equipment amount and equilibrium degree of handling times, the makespan was taken as the constraint were integrated in a multi-objective decision-making model to select the appropriate operation organization mode and to determine the optimal scheduling scheme [17].

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