Impact of credit and training on enterprise performance: Evidence from urban Ethiopia *

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Abstract

This study employees endogenous switching regressions for the case of multiple treatments to evaluate the impact of a set of business development support programs (credit, training and both) on MSEs performance using the Ethiopian urban survey data of 2015. We document a positive and significant treatment effect of credit, training, and combination of training and credit on the MSEs performance. Our results also highlight the heterogeneity in treatment effects between female and male owned MSEs: female-owned MSEs do not benefit from access to treatments (credit only, training only or both). The heterogeneity in treatment effects highlights the different needs of the MSEs to improve firm performance. Results suggest that improving the MSEs performance requires fine-tuned interventions that meet the specific needs of male and female-owned MSEs than one-size fits all programs.

Key words: Treatment effects, MSEs, gender, Ethiopia
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Contents

1 Introduction

A sizeable number of jobs are created by the small and medium enterprises (SMEs), they account for two thirds of all the jobs worldwide (ILO, 2015) and about 60% of GDP in the developing countries (Deijl et al., 2013). The role of small and medium enterprises in creating jobs, innovation and adoption of technology, broadening the tax base and risk diversification is well recognized (Vijverberg, 1991; McPherson, 1996; Daniels and Mead, 1998; Mead and Liedholm, 1998). One of the main characteristics of a flourishing economy is a vibrant micro and small enterprises (MSEs) sector. Among others, the role of MSEs as engines of growth in transition economies is evidenced by China's recent growth (Anderson et al., 2003; Wang, 2016). In developing countries, with growing populations, high levels of unemployment and low economic growth, it is very important to encourage creation and expansion of businesses that generate new jobs and enhance economic growth. MSEs also facilitate inclusive growth by empowering women through increasing their participation in the labor market.

In developing countries, about 10 million MSEs are owned by women, which represents roughly a third of all formal and registered MSEs (ILO, 2015). Thus, supporting and promoting women-led MSEs is critical to promote inclusive growth; since economic empowerment of women who constitute about half of the potential workforce has a vital economic importance than only promoting gender equality (Duflo, 2012). This has led policymakers to give more emphasis to women enterprise development. As a result, the last two decades have witnessed flourishing women-owned MSEs.[1] The rising number of women-owned MSEs has attracted a considerable amount of research that compared male and female entrepreneurs and their businesses. Klapper and Parker, 2010 review the existing literature and conclude that there exists increasing evidence that women MSEs tend to underperform relative to their male counterparts in terms of earnings, profits, rates of return on capital, venture growth rates, and firm survival rate. The underperformance of female-owned MSEs persists after controlling for classic business performance indicators such as industry, the age of business, and size of business (Watson and Robinson, 2003). Understanding what explains this gender disparity and its policy implication to encourage female entrepreneurs in MSE sector is hence an immediate consequential research issue in the developing world.

For all MSEs businesses, regardless of the owner's gender, access to external finance is the most important source of external funding (Berger and Udell, 1998), and for women owned businesses, the empirical evidence shows that securing external financing is one of the key challenges to improve their performance (Chaganti et al., 1996; Coleman, 2000; Minniti, 2009; Jamali, 2009). In most developing countries, women entrepreneurs in MSE sector appear to have less access to external sources of capital than men (Kelley et al., 2012). Financial market imperfections in developing countries particularly in Africa is also constraining for women-owned small entrepreneurs who lack

[1] IFC (2011) estimated that MSEs with full or partial female ownership represent 31% to 38% of formal MSEs in developing countries.

collateral, credit histories, and social connections (Asiedu et al., 2013).

Several theoretical and empirical studies have discussed the role of finance in firm growth and compared the results of MSEs with those of large firms. Stiglitz and Weiss (1981), De Meza and Webb (1987) and Evans and Jovanovic (1989) gave theoretical explanations on the reasons behind small enterprises' financial constraints. Demirgüç-Kunt and Maksimovic (1998), Ayyagari et al. (2008), Bigsten et al. (2003), and Fafchamps (2003) empirically show that MSEs often face financial constraint during both start-up and expansion, and relaxing the financial constraint of the firms could enable them to grow faster. Beck and Demirguc-Kunt (2006) suggest that improving access to finance for firms results in relatively better growth in small firms than large ones. Other studies (e.g. Nichter and Goldmark, 2009; Love, 2003; Wurgler, 2000) also show that access to finance is a key determining factor that enhances enterprise performance by improving the level of revenue/profit and employing more workers. Nichter and Goldmark (2009) find that access to bank credit is the main determining factor for the growth of micro and small enterprises. This result is alike to those in Love (2003) and Wurgler (2000) that report a significant contribution of finance access on MSE performance.

Lashitew et al. (2011) demonstrates that credit access has a significant negative effect on the cost of capital. This confirms that access to credit allows firms to employ more capital to boost MSE performance. Reduction in the firm's operating costs could come directly from investing in more productive capital equipment whereby increased demand could stimulate and improve the expansion of enterprise performance. Access to external finance may allow firms to have a better capacity to acquire necessary working capital and technical inputs, and that could allow firms to have favorable impacts on MSE profitability. More specifically their study illustrates that access to finance, particularly bank credit, has a strong positive effect on firm profitability performance. Badia et al. (2008) also show that financial constraints do lower firm performance.

Standard models of investment also predict that credit-constrained firms grow faster when given additional capital (Fafchamps et al., 2011). This view partly led to microfinance institutions to lend more credit to MSEs, since small firms can earn high returns to capital given access to finance. However, the evidence of high marginal returns to capital from MSEs raised doubts on empirical credibility ground. Evidence-based on randomized control trials by Fafchamps et al. (2011), De Mel et al. (2008), and Karlan and Zinman (2009) confirm the doubt. Fafchamps et al. (2011) found large and positive average treatment effects of in-kind grants for both men and women entrepreneurs in urban Ghana. However, they reported almost zero gain in profit for women with initial profit below the median. Similarly, De Mel et al. (2008) and De Mel et al. (2009) also reports a positive and high return to capital for micro-enterprises in Srilanka, with no positive return for women-owned enterprises. Karlan and Zinman (2009) report a shrink in business investment size and scope and only some gains in profit for men borrowers.

Upgrading knowledge-base and skill of all types of workers and managers is also central to improve enterprise performance. Education usually provides entrepreneurs with a capacity to learn

about new production processes and product designs and provides specific technical knowledge appropriate to enterprise growth among others. Panjaitan-Drioadisuryo and Cloud (1999) and Singh and Belwal (2008)) argue that entrepreneurial skill is a major driver to improve micro and small enterprises performance, which can be acquired through training. In this regard, training enables MSEs owners and participants to change behavior and perceptions about their activities that are directly associated with MSEs performance. Other empirical studies show that enterprises with better-educated owners and managers tend to be more productive (Little et al., 1987; Burki and Terrell, 1998). While others (e.g. Alvarez and Crespi, 2003) argue that education may hamper MSE growth and lower efficiency in cases when owners redirect their attention to other attractive opportunities. The empirical evidence on the effect upgrading entrepreneurial skill is mixed. For instance, Karlan and Valdivia (2011) found no significant effect of business training on the performance of both men and women-owned MSEs in Peru, while Bergemann and Van den Berg (2008), found a strong positive effect on male entrepreneurs but insignificant effect on female entrepreneurs in selected EU countries. On the other hand McKenzie and Puerto (2017) recently documented a positive effect of business training for female MSE performance (profits, sales and businesses survival) in Kenya.

Although there is a growing body of literature addressing the impact of financing and upgrading entrepreneurial skill of MSEs, not enough is known about the joint effects of the two development support programs to MSEs (access to credit and training) on the performance of women and men-owned small businesses, and this warrants further research. While there is a common belief that access to external financing and upgrading knowledge-base of entrepreneurs improve the performance firms particularly that of MSEs, we are unaware of any convincing evidence on gender differences in the effect of capital and business training on MSE performance. In this paper, we evaluate the impact of access to credit, business training and the combination of both on the performance of female and male-owned MSEs in urban Ethiopia. Methodologically, we use endogenous switching regressions for multiple treatments to evaluate the impacts of credit, of training, and of credit-cum-training on MSEs monthly revenue after controlling for both firm and firm owner characteristics such as firm size, sector, age, risk appetite and experience of owners among others.

Our results show positive and significant effects of credit, of training and of the combination of credit and training on monthly revenue of the MSEs. However, in line with the scant empirical evidence, our results highlight the heterogeneity in treatment effects between female and male-owned MSEs: female-owned MSEs do not benefit from access to treatments (credit only, training only or both). On the other hand, access to credit, to training and to credit and training leads to a higher return on monthly revenue of men-owned firms compared to not receiving any of these treatments. Male entrepreneurs benefited the most from access to credit and training simultaneously. The results for male-owned MSEs clearly highlight the complementarity nature of the treatments. The findings shed light on the demand for fine-tuned interventions to meet the specific needs and demands of women-owned MSEs.

We begin with a description of the used data and the context of the study. Thereafter, we describe the methodology used to test our hypotheses. A discussion of the results is followed by a robustness check, conclusions and suggestions for policy.

2 Data

2.1 Definition and context

Micro, Small and Medium Enterprises (MSMEs) in Ethiopia cover a wide range of business activities which can broadly classify into industry and service sectors. The industry sector is composed of manufacturing, construction, and mining while the service sector includes retailer, transport, hotel and tourism, ICT and maintenance service (CSA, 2015). Labor force and the level of automation of the enterprises were used for the classification of MSMEs. Based on these, two types of working definitions were usually used by the Ethiopian Ministry of Trade and Industry (MoTI) and the Ethiopian Central Statistics Authority (CSA). The definition of MoTI (1997) classifies MSMEs based on the level of capital investment of the firm, while the CSA classify enterprises into different categories based on total full-time employees and level of automation of the firm. With the main objective of reflecting the current situation of the country and harmonize the national definition of MSMEs with international definition, MoTI (2011) in the Micro and Small Enterprise Development Strategy makes a clear classification of MSMEs based on total assets and human power of the enterprises.[2] Table 1 below summarizes current definition of MSMEs in the country with their respective sector.

Table 1 – Classification of enterprises in Ethiopia

Level of the Enterprise	**Sector**	**Human power**	**Total Asset**
Micro Enterprise	Industry	< 5	$<$ Birr 100,000 ($6,000)
	Service	< 5	$<$ Birr 50,000($3,000)
Small Enterprise	Industry	$6 - 30$	<Birr 1.5million ($90,000)
	Service	$6 - 30$	$<$ Birr 500,000 ($30,000)
Medium and large scale	Industry	> 50	>Birr 1.5 million ($90,000)
	Service	> 50	>Birr 500,000 ($30,000)

Source: MoTI (2011) .

In Ethiopia, MSEs occupy the lion share of private sectors. Like other developing countries Ethiopia can benefit hugely from MSEs development. The significance of MSE development in the country becomes clearer when one looks at the employment profile of the country. Urban employment to population ratio is 49.4%, females having low employment to population ratio

[2]When ambiguity is encountered between man power and total assets as explained above, total asset is taken as primary yardstick.

of 40% (CSA, 2011). Significant proportions of the urban employed population are self-employed, accounting for 38.9%, followed by a Government employee of 21.2%. The informal sector contributes about 36.5% of total employment in urban areas and females dominate the sector (CSA, 2011). The unemployment rate in Ethiopia is 18%. The unemployment rate is even higher for youth (15-29) which is 23.7 %. The unemployment rate is more than double for females (25.3%) as compared to males (11.4%). Past development initiatives in Ethiopia focus on agricultural sector development. Despite those efforts, the productivity of that sector is low. In addition, the presence of high population growth together with limited arable land limits the sector from providing employment for a significant proportion of the population. A number of micro-level studies (Woldehanna, 2000; Dercon, 2006; Bekele and Muchie, 2009) also support the claim. Hence, curbing unemployment in the country is expected to come from the development of the non-farm sector.

Cognizant of the fact that the MSEs could contribute in employment generation, GDP growth and poverty reduction, the Government of Ethiopia (GoE) has put in place an MSE development strategy and establish the Federal Micro and Small Enterprises Development Agency (FeMSEDA) in 1997. The country has also launched many initiatives, development policies and plans to achieve economic growth, lower unemployment, and industrial development. The Micro and Small Enterprises Development strategy, Industrial policy, and the Growth and Transformation Plan I and II are such efforts that include MSEs development targets. [3] Despite government efforts, MSEs in Ethiopia faces many constraints. According to CSA (2004), survey on urban informal sector, the six major problems faced by MSE entrepreneurs are a lack of sufficient capital, inadequate skills, lack of premises, lack of technology transfer, low access to market and lack of market information. To address the constraints, the Growth and Transformation Plan (GTP)-I and GTP II emphasized on provision of capital for MSEs through saving and credit institutions, integrating the MSEs with Technical and Vocational Educational Training (TVET) system to provide necessary skills and education. The current five-year development plan of the country, GTP-II, boldly sets the importance of sustaining broad based economic growth in order to eradicate poverty and *create employment*. In the GTP, one among the strategic pillars is creating favorable condition for industry to play a key role in the economy in terms of generating foreign exchange and *creating employment opportunities for the growing labor force*. In the industrial sector, the government focuses on strengthening small scale manufacturing enterprises, since they are the foundation for establishment and expansion of medium and large-scale industries, *open opportunities for employment generation*, expansion of urban development and provide close support for further agricultural development.

To address the challenges faced by MSEs and promote growth in the sector, the government restructured the institutional organization FeMSEDA at federal, regional and city level. FeMSEDA is responsible for formulating the overall support framework of the sector. The regional bodies and the one-stop shop facilities at the city level are responsible for ensuring the proper implementation

[3]The National MSEs development Strategy was formulated in 1997 and was revised in 2010/2011 to address the implementation gap in the first strategy with more ambitious targets on enterprise and employment numbers (EEA, 2015; Assefa et al., 2014).

of the development of the strategy at the micro level. Currently, there are 1,097 one-stop shop services centers throughout the country and provide comprehensive support service to MSEs. To alleviate the financial constraints of MSEs, for instance, the state government established a credit guarantee fund and saving programs to lease machine. Both schemes aim to solve MSEs capital and assets constraints and enable to access credit without collateral. According to National Bank of Ethiopia, 271, 519 MSEs have accessed a total of 6.5 billion Birr loan from banks and microfinance institutions from 2008 to 2015 (NBE, 2014/15). In terms of developing technical and managerial know-how of MSEs attention is given in providing training in entrepreneurship, skill development, and business management. Currently, there are more than 300 Technical and Vocational Education and Training centers (TVET) in the country providing capacity development training to MSE entrepreneurs (World Bank, 2015).

2.2 Sampling strategy

We use firm-level data collected in 2015 by Addis Ababa University and Addis Ababa City Administration Micro and Small Enterprise Development Bureau. The objective of the survey is to obtain information on the major constraints and challenges that have been facing MSEs in Addis Ababa as well as to help in building a panel of MSEs data that track changes in the performance of firms over time, thus allowing, for example, impact assessments of government support programs.[4] The sampling is done using the database of Addis Ababa City Administration Micro and Small Enterprise Development Bureau, which constituted micro and small firms operating in the city in major sectors such as manufacturing, construction, trade and urban agriculture. The survey follows the definition of Ethiopian Ministry of Trade and Industry (MoTI) to classify micro and small enterprises.

With the objective of ensuring representation of every sub-sector, a two-staged stratified sampling procedure is applied. First, MSEs are categorized into two sector strata: manufacturing and non-manufacturing. Then, each sector, manufacturing and non-manufacturing, is classified into non-overlapping strata of sub-sectors using MOTI classification. A proportional stratified sampling based on the available sub-sectors is drawn. Then, within each sub-sector or the strata, the sample is drawn randomly using simple random sampling.

The data size is 1,445 sampled MSEs operating in Addis Ababa. The survey collected information on firms' characteristics (age, size, owner's gender, education, experience, workforce composition), access to business support services (access to finance, training, land and other support services), licensing status (formality and legality), performance measures (annual sales and employment), sectoral distribution and challenges of MSEs. The survey also provides details of firms' activities and use of inputs, the value of output and inputs over the last 12 months before the survey. The dataset enables to answer the proposed research questions and gives a good picture

[4]The sampling frame of the survey, Addis Ababa, is the biggest metropolitan city representing the largest center of MSEs in the country (World Bank, 2015).

of MSE sector in the urban area of the country.

As discussed in the previous sections, the government of Ethiopia, in collaboration with other development actors, is implementing various programs such as the provision of training, technology transfer and access to finance for MSEs in urban areas. The development of the MSE sector is justified on the grounds promoting inclusive growth, creating sustainable employment, especially for youth and women, providing a foundation for large manufacturing enterprises and promotion of exports. Accordingly, access to any of the treatment (credit, training or both) is expected to enhance the performance of MSEs in terms of revenue, profit or employment creation among others.

3 Methodology

Standard models of investment predict that entrepreneurs financially constrained grow fast when given additional finance (Fafchamps et al., 2011). The type of finance should not affect their investment decision or consumption of the capital. Similarly, De Mel et al. (2008) formally show that missing financial (both credit and insurance) market result in high marginal return to capital. In contrast, Karlan and Valdivia (2011) doubt the "poor but rational" presumption behind the microfinance intervention that focus on provision of credit and saving products for micro-entrepreneurs. Since most of the micro-entrepreneurs have no formal business training and may fail to optimally manage their business. Therefore, in this study, we test *whether relaxing financial constraint result in to growth of MSEs, whether business training or combination of the two have an impact on MSEs performance and importantly, does the impact vary by gender.*

To find the treatment effects of access to credit and training on enterprise performance, we apply multinomial endogenous switching regression for multiple treatments. Moreover, for checking the robustness results, we apply propensity score estimation for multiple treatments following Imbens (2000) and Lechner (2001).[5] In the context we are working on, it is plausible to argue that unobserved characteristics of MSE entrepreneurs such as motivation to work, entrepreneurial ability, and aspiration of MSE owners to expand business might influence self-selection to the treatment. Hence, our preferred treatment effect estimates are results from multiple endogenous switching regression.

3.1 Notation and definitions

In micro-econometric evaluation, an individual faces two states of the world, participation in a program or non-participation in such a program. In either case, an individual gets two potential outcomes for each state. Causal effect is defined as the difference between these potential outcomes. This is commonly known as Roy-Rubin Model (Rubin, 1974).

Let there be $(M+1)$ mutually exclusive treatments in which the potential treatments are denoted

[5]Refer to appendix A and B for detail discussion on identification and the methodology we follow to estimate treatment effect for multiple treatments using Propensity score matching approach, respectively.

as $(Y^0, Y^1, \ldots, Y^M)$. For each individual, only an element of the potential treatments is observable and the remaining are counterfactuals. Participation in a particular treatment is indicated by the variable $T \quad \{0, 1, \ldots M\}$. Each individual has M+1 potential outcomes, but only the one corresponding to the observed treatment (T_i) is observed. That is, if for a given unit i, $T_i = t$, then $Y_i = Y_i[t]{=}\mu_t$. In the multiple treatments framework, the definition of average treatment effect (ATE) and average treatment effect on the treated (ATT) developed for binary treatment needs adjustment. Here the focus is on the relative effectiveness of all possible pairs of treatments.

Average treatment effect (ATE): ATE of treatment $t^{'}$ relative to $t^{''}$ is the comparison of mean outcomes had the entire population been observed under one treatment $t^{'}$ versus had the entire population been observed under another treatment $t^{''}$ (Wooldridge, 2010 and McCaffrey et al., 2013). Formally, ATE (denoted by $\tau_{ate}^{t^{'}t^{''}}$) is:

$$\tau_{ate}^{t^{'}t^{''}} = \mu_{t'} - \mu_{t''} \tag{1}$$

Average treatment effect on the treated (ATT): In the multiple treatments case, the ATT focus is on the pairwise comparison of the effects of treatments $t^{'}$ and $t^{''}$ for one of the participants in either $t^{'}$ or $t^{''}$. formally, the multiple treatments version of ATT is:

$$\tau_{att}^{t^{'}t^{''}} = \mu_{t't''} - \mu_{t't'} \tag{2}$$

ATT of treatment $t^{''}$ among those treated with $t^{'}$ (stated as ATT of $t^{'}$ relative to $t^{''}$) is the comparison of those who were treated with $t^{'}$, of their mean outcome when treated with $t^{'}t^{''}$, as they were, with the mean outcome they would have had if they had instead been treated with treatment $t^{''}$ (Wooldridge, 2010).

In the multiple treatments case, there are several quantities of interest and the choice depends on the research question the study would like to address. When the interest is to offer the treatment for all the members of MSEs, estimating ATE would provide more relevant information. For instance, if the interest is to provide training for every MSEs operator, we need to estimate and know the ATE.

When the interest is to understand the relative effectiveness of an intervention versus another intervention, ATT provides appropriate information. Moreover, if the interest is also to know the appropriateness of an intervention or a particular group, ATT provides relevant quantities of the treatment effect. In this study, we propose to estimate both ATE and ATT, given in Table 2.

3.2 Treatment Effect Model for Multiple Treatments: Multinomial endogenous switching regression approach

The representative entrepreneur's choice of accessing finance, training or their combination could be endogenous due to self-selection. The decisions are systematically influenced by both observable and unobservable factors, which may correlate with the outcome of interest. To address the possible

Table 2 – ATE and ATT of multiple treatments*

	ATE	**ATT**		
		Credit (cr)	Training (tr)	Both (crtr)
Credit vs. Training	$\mu_{cr} - \mu_{tr}$	$\mu_{cr,tr} - \mu_{cr,cr}$	$\mu_{tr,cr} - \mu_{tr,tr}$	§
Credit vs. both	$\mu_{cr} - \mu_{crtr}$	$\mu_{cr,crtr} - \mu_{cr,cr}$	§	$\mu_{crtr,cr} - \mu_{crtr,crtr}$
Training vs. Both	$\mu_{tr} - \mu_{crtr}$	§	$\mu_{tr,crtr} - \mu_{tr,tr}$	$\mu_{crtr,tr} - \mu_{crtr,crtr}$

*It is possible to compute the ATE in comparison to the groups that did not receive any treatments.
§These are nonsensical cases to estimate the ATT.

selection biases, we use multinomial endogenous switching regression originally proposed by Dubin and McFadden (1984). [6] The approach allows to get both consistent and efficient estimates of the selection process and a reasonable correction for the outcome equations, even when the assumption of the independence of irrelevant assumptions (IIAs) is not achieved. In the first stage, we model the selection/treatment decision (choice of credit, training, their combination or neither) using multinomial logit selection model that recognizes the interrelationship among them. In the second stage, the impacts of each treatment on MSEs performance are evaluated using OLS corrected for selectivity.

Multinomial logit selection model

In a random utility framework, it is assumed that a representative entrepreneur chooses an alternative that provides the highest utility. Formally, a latent model (T_{ji}) that describes entrepreneur i's choice for treatment j over another alternative m.

$$T_{ji} = \gamma_j z_i + \varepsilon_{ji} \tag{3}$$

z_i is the vector of observable characteristics that affect choice of treatment and ε_i is the unobservables. The utility of choosing an alternative is not observed, while the actual choice of the alternative is observed. An entrepreneur's choice of an alternative j over another alternative m is

[6] Bourguignon et al. (2007) presents the survey of methods that address selection bias, when selection is specified as a multinomial logit model, and contrast the underlying assumptions used by the methods. They conclude that the approach proposed by Dubin and McFadden (1984) is a preferred method and further propose a variant of the Dubin and McFadden (1984) method. Accordingly, we follow the suggestion in Bourguignon et al. (2007) to address the selection bias.

given as follows.

$$T^*_{ji} = \begin{cases} 0 \; if \; T^*_{ji} > \max_{m \neq 1} T^*_{mi} \;\; or \;\; \omega_{0i} < 0 \\ \quad . \quad . \quad . \\ \quad . \quad . \quad . \\ \quad . \quad . \quad . \\ J \; if \; T^*_{ji} > \max_{m \neq j} T^*_{mi} \;\; or \;\; \omega_{ji} < 0 \end{cases} \tag{4}$$

Where $\omega_{ji} = \max_{m \neq j}(T_{mi} - T_{ji}) < 0$ (Bourguignon et al., 2007). Eq. 4 implies that entrepreneur i chooses alternative j over m as far as the utility from j is greater than from m for $m \neq j$.

Assuming that ε is an identically independently Gumbel distributed, the probability that an entrepreneur i chooses a treatment j given characteristics z can be given as a multinomial logit model (McFadden et al., 1973).

$$p_{ji} = pr(\omega_{ji} < 0 \,|z) = \frac{\exp(\gamma_j z_i)}{\sum_{m=1}^{J} \exp(\gamma_m z_i)} \qquad j = 1, 2, \ldots, J \tag{5}$$

Multinomial endogenous switching treatment regression

To estimate the impact of each treatment on MSEs performance, we specify the following multinomial endogenous switching regressions as in Eqs. (6a)–(6d):

$$y_{ni} = \beta_n x_i + u_{ni} \qquad if \quad T = 0 \tag{6a}$$

$$y_{cri} = \beta_{cr} x_i + u_{cri} \qquad if \quad T = 1 \tag{6b}$$

$$y_{tri} = \beta_{tr} x_i + u_{tri} if \qquad if \quad T = 2 \tag{6c}$$

$$y_{crtri} = \beta_{crtr} x_i + u_{crtri} \qquad if \quad T = 3 \tag{6d}$$

However, due to the possible correlation between the unobservable in the outcome equation (6a)–(6d) and the selection equation, estimating Eqs. (6a)–(6d) using OLS yields biased results. Hence, Bourguignon et al. (2007) indicate that consistent estimates of the parameters in Eqs (6a)–(6d) require correction for selectivity. They show that consistent estimates of the parameters are obtained by introducing a correction term, in the in Eqs. (6a)–(6d) as given in Eqs. (7a)–(7d) and apply OLS.

$$y_{ni} = \beta_n x_i + \sigma_n \lambda_n + \xi_{ni} \qquad if \quad T = 0 \tag{7a}$$

$$y_{cri} = \beta_{cr} x_{ji} + \sigma_{cr} \lambda_{cr} + \xi_{cri} \qquad if \quad T = 1 \tag{7b}$$

$$y_{tri} = \beta_{tr} x_{ji} + \sigma_{tr} \lambda_{tr} + \xi_{tri} \qquad if \quad T = 2 \tag{7c}$$

$$y_{crtri} = \beta_{crtr} x_{ji} + \sigma_{crtr} \lambda_{crtr} + \xi_{crtri} \qquad if \quad T = 3 \tag{7d}$$

Where σ_u is the covariance between ε and u; λ is the correction term derived based on estimated probabilities from Eq. 5 and the correlation (ρ) between ε and u.

Estimating the conditional expectations and treatment effects

After consistently estimating the Eqs. (6a)–(7b), we can compute the conditional expectations of each equation when the dependent variable is observed and its counterfactual as given in Eqs. (8a)–(9b)

Expected value of MSE revenue for Untreated entrepreneurs:

$$E(y_{ni}T = 0) = \beta_n x_i + \sigma_n \lambda_n \tag{8a}$$

Expected value of MSE revenue for Treated entrepreneurs:

$$E(y_{cri}|T = 1) = \beta_{cr} x_i + \sigma_{cr} \lambda_{cr} \tag{8b}$$

$$E(y_{tri}|T = 2) = \beta_{tr} x_i + \sigma_{tr} \lambda_{tr} \tag{8c}$$

$$E(y_{crtri}|T = 3) = \beta_{crtr} x_i + \sigma_{crtr} \lambda_{crtr} \tag{8d}$$

Counterfactuals for untreated entrepreneur: Expected value of MSE revenue for the untreated had they received the treatment:

$$E(y_{ji}|T = 0) = \beta_j x_i + \sigma_j \lambda_n \tag{9a}$$

Counterfactuals for treated entrepreneur:

Expected value of MSE revenue for those that received j had they did not receive any support:

$$E(y_{ni}|T = j) = \beta_n x_i + \sigma_n \lambda_j \tag{9b}$$

The ATE and ATT could be computed as in Eq. (10a)–(10b) and (11a)–(11b), respectively. *t' and t" are treatments in j.*

$$ATE_j = E(y_{ji}|T = j) - E(y_{ni}|T = n) = \beta_j x_{ji} + \sigma_j \lambda_j - \beta_n x_{ni} + \sigma_n \lambda_n \tag{10a}$$

$$ATE_{t't''} = E(y_{t'}|T = t') - E(y_{t''}|T = t'') = \beta_j x_i + \sigma_j \lambda_j - \beta_n x_{ni} + \sigma_n \lambda_n \tag{10b}$$

$$ATT_j = E(y_{ji}|T = j) - E(y_{ni}|T = j) = (\beta_j x_i + \sigma_j \lambda_j) - (\beta_n x_i + \sigma_n \lambda_j) \tag{11a}$$

$$ATT_{t't''} = E(y_{t''}|T = t') - E(y_{t'}|T = t') = (\beta_{t''} x_i + \sigma_{t''} \lambda_{t'}) - (\beta_{t'} x_i + \sigma_{t'} \lambda_{t'}) \tag{11b}$$

4 Results

4.1 Descriptive results

Table 4.1 offers the descriptive statistics of the key variables used in the analysis disaggregated by treatment status. The average annual revenue in the sample is Birr 55,586.[7] Overall, treated MSEs, have higher monthly revenue than the untreated counterparts. The difference in monthly revenue between treated and untreated firms is statistically significant at 1%. Firms that receive both treatments (Capital and training) have the highest monthly revenue, followed by MSEs that receive training and firms have access to credit (see Table 4.1).

The majority of MSEs (38%) are engaged in the manufacturing sector. The average age of the firms is 4.76 years. The firms reported an average of Birr 35,635.84 (USD 1500.00) initial capital and have 3 employees on average. In terms of education, the majority of employees (65%) have less than or completed high school education, 26% have a diploma, while 9% have a first degree. Overall, younger firms, firms with more members and employees, firms with higher initial capital, firms with higher human capital (more educated employees), firms that prepare regular financial reports, firms that uses IT systems, firms engaged in manufacturing and construction sectors have higher access to treatments (credit, training or both) than the comparison MSEs (see Table 4.1). This descriptive results might suggest that access to the different treatments might depend on observable characteristics of firms.

With regard to ownership characteristics, 30% of the owners of MSEs are females, has 11 years of schooling and has been engaged in MSE sector for 7 years. The coefficient of relative risk aversion is calculated using Antle (1987) moment-based approach.[8] The mean estimate of relative risk aversion is 0.015, indicating owners of MSEs in Ethiopia are risks averse.

[7] This is 1% trimmed mean.

[8] Refer part I "Entrepreneurial risk attitude in the Micro and Small Enterprises: Evidence from urban Ethiopia" for details.

Table 3 – Descriptive statistics by treatment type

	Credit		Training		Credit and Training		Untreated		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Outcome indicator:										
Monthly sales revenue (in log)	5.33	5.54	8.25	4.46	8.98	4.24	4.81	5.05	6.69	5.11
Firm characteristics										
Age of the enterprise	4.77	3.95	4.42	3.3	4.73	3.6	5.02	4.5	4.76	3.95
Total initial capital of the enterprise (in Birr)	43 746.62	130 095.00	41 609.12	183 338.00	59 904.61	149 912.80	19 625.75	69 092.04	35 635.84	135 183.90
Total number of employee	3.06	8.21	3.6	6.36	4.79	8.18	1.96	5.98	3.07	6.8
Financial reports (1 if MSE prepare financial reports)	0.37	0.48	0.36	0.48	0.46	0.5	0.21	0.41	0.32	0.47
Monthly labor cost	5652.03	25 326.98	5 790.70	26 135.41	10 430.30	28 086.89	34 369.09	807 101.40	18 765.88	526 972.60
Monthly material costs	34367.45	99 629.88	24 330.13	44 387.17	27 555.22	34 502.83	18 041.28	89 521.28	22 954.16	70 144.88
Employees Education										
High school*	0.32	0.47	0.38	0.49	0.35	0.48	0.45	0.5	0.4	0.49
Below high school	0.32	0.47	0.2	0.4	0.16	0.37	0.32	0.47	0.25	0.43
Diploma	0.22	0.41	0.32	0.47	0.37	0.48	0.17	0.38	0.26	0.44
First degree and above	0.15	0.36	0.1	0.3	0.12	0.32	0.07	0.25	0.09	0.29
Sector										
Manufacturing*	0.32	0.47	0.51	0.5	0.4	0.49	0.27	0.45	0.38	0.48
Service	0.07	0.26	0.09	0.28	0.07	0.26	0.18	0.39	0.12	0.33
Construction	0.16	0.37	0.27	0.44	0.31	0.47	0.14	0.35	0.21	0.41
Trade	0.44	0.5	0.13	0.34	0.21	0.41	0.4	0.49	0.28	0.45
Owners characteristics										
Gender of entrepreneur	0.37	0.48	0.25	0.43	0.23	0.42	0.35	0.48	0.3	0.46
Experience in MSEs (Years)	6.13	5.05	6.55	5.53	6.85	5.58	6.41	5.97	6.51	5.69

Note: 1 USD is equivalent to 26.96 Birr since October 11, 2017.

∗ Represent the comparison group

Disaggregating access to treatments by gender of owners of MSEs suggests that women-owned firms have lower access to all the treatments. The difference in access to training and capital-cum-training is significant at 1%. The result, at first glance, suggests that female entrepreneurs have limited access to credit, training, and capital-cum-training than their male counterparts. This first observation is in line with the findings of Asiedu et al. (2013), who document those female entrepreneurs have less access to credit in Africa but not in other parts of the world (see Table 4). The difference in access could originate from characteristics of the MSEs.

Table 4 – Summary statistics by gender of entrepreneur

	Female		**Male**	
	Mean	SD	Mean	SD
Outcome indicator:				
Monthly sales revenue (in log)	4.822	4.894	7.475	4.993
Firm characteristics				
Age of the enterprise (in years)	4.864	3.938	4.713	3.959
Initial capital of the enterprise (in Birr)	19249.52	68802.63	42506.48	154280.8
Total number of employee	1.768	5.062	3.614	7.338
Financial reports	0.2	0.4	0.365	0.482
Monthly labor cost	3006.23	15541.71	25373.76	627696.6
Monthly Material costs	11186.81	45245.22	27636.58	77393.86
Education of employees				
High school	0.432	0.496	0.382	0.486
Below high school	0.35	0.477	0.212	0.409
Diploma	0.178	0.383	0.291	0.455
First degree and above	0.04	0.196	0.115	0.319
Sector				
Manufacturing	0.286	0.453	0.414	0.493
Service	0.192	0.395	0.095	0.294
Construction	0.075	0.264	0.274	0.446
Trade	0.446	0.498	0.217	0.412
Owners characteristics				
Experience in MSEs (Years)	5.885	5.195	6.769	5.873
Relative risk premium	0.0176	0.030	0.0136	0.031
Treatments				
Credit	0.235	0.424	0.261	0.439
Training	0.406	0.492	0.535	0.499
Capital and training	0.138	0.346	0.192	0.394

Table 5 shows that on average, female-owned MSEs in our sample are older, engaged in service and trade sector, have fewer employees with lower educational attainment and lower experience in the MSEs sector than their male peers. When it comes to risk-taking, there is again a gender-based difference. Women entrepreneurs in our sample are more risk averse than the male counterparts, the difference in the relative risk premium is significant at 5%.[9]

[9]See part I on "Entrepreneurial risk attitude in the Micro and Small Enterprises: Evidence from urban Ethiopia".

Table 5 – characteristics of female treated firms by treatment type

	Female - credit		Female training		Female credit and training	
	Mean	SD	Mean	SD	Mean	SD
Outcome indicator:						
Monthly sales revenue (in log)	3.534	4.781	6.721	4.658	7.188	4.826
Firm characteristics						
Age of the enterprise (in years)	5.488	3.613	4.693	3.782	4.678	3.844
Initial capital of the enterprise (in Birr)	26668.9	45549.31	22731.75	43082.95	43410.93	162665.2
Total number of employee	1.366	3.706	2.14	3.991	3.407	6.767
Financial reports (yes=1)	0.22	0.419	0.211	0.409	0.322	0.471
Monthly labor cost	1970.371	9587.353	6137.733	26259	6029.413	17221.65
Monthly Material costs	5701.429	11375.3	13297.18	27625.8	18611.15	24013.33
Education of employees						
High school	0.293	0.461	0.447	0.499	0.407	0.495
Below high school	0.439	0.502	0.298	0.46	0.271	0.448
Diploma	0.195	0.401	0.211	0.409	0.271	0.448
First degree and above	0.073	0.264	0.044	0.206	0.051	0.222
Sector						
Manufacturing	0.244	0.435	0.412	0.494	0.356	0.483
Service	0.098	0.3	0.193	0.396	0.153	0.363
Construction	0.073	0.264	0.123	0.33	0.169	0.378
Trade	0.585	0.499	0.272	0.447	0.322	0.471
Owners characteristics						
Experience in MSE Sector (Years)	6.22	4.252	5.675	4.507	5.661	5.141
Relative risk premium	0.112	0.029	0.118	0.079	0.105	0.034

Table 5 also disaggregate the characteristics of women-owned MSEs that have access to treatments (credit or training or both credit and training). Women-owned firms that have access to both credit and training have on average higher monthly revenue than their peers that receive either credit or training only. Overall young woman firms, women firms that have higher initial capital, large firms (with a higher number of employees and members), firms that prepare monthly financial reports have more access to both credit and training simultaneously than their peers. On the other hand, women-owned firms with a more risk averse owner, engaged in the manufacturing sector have more access to training than the other treatments. With regard to credit access, firms that are owned by older entrepreneurs, with lower educational attainment and engaged in trade sector have a better access.

4.2 Econometric results

In this section, we address the evaluation questions: the impact of access to credit, training and the combination of both credit and training on the performance of MSEs. The impact analysis is based on multiple treatment effects estimation using multinomial endogenous switching regression (MESR) model. First, we present the multiple treatment effects estimates for the whole population, for both male and female owned MSEs. Second, we provide an assessment of heterogeneity in impacts by gender of the entrepreneurs.

Multiple treatment effects estimates

Table 6 and Table 7 present the estimated treatment effects for all MSEs in our sample. The ATE shows the difference in revenue for receiving a treatment by all entrepreneurs and the comparison group had they received another treatment or being untreated. Thus, first we compute the ATE comparing the treated MSEs versus those untreated. Second, we compute the ATE comparing a treatment versus another treatment.

Table 6 – ATE of multiple treatments–All

Outcome variable–Monthly sales revenue, ALL - ATE			
Credit vs. Untreated	0.422*	Credit vs. Training	-0.790**
Training vs Untreated	1.211***	Credit vs. Both	-1.648***
Both vs Untreated	2.069***	Training vs. Both	-0.858 ***

$*p < 0.1, **p < 0.05, ***p < 0.01$

The ATE of receiving credit for all entrepreneurs in comparison to all entrepreneurs being untreated is about 42% increase in log revenue per month. The large average return to capital is in line with previous studies in Ghana and Sri Lanka; in Ghana one time grant is estimated to increase monthly profit by about 26% and in Sri Lanka the average return to capital is estimated to

be 6% per month (Fafchamps et al., 2011; De Mel et al., 2008). The ATE of going from untreated to training and both (receiving training and credit simultaneously) doubles the monthly revenue of treated MSEs, both impacts are significant at 1% (see Table 6). The results suggest that provision of credit, training or a combination of credit and training positively affect the performance of MSEs compared to have not received any of these treatments.

When we compare the impact of a treatment versus another treatment, the ATE of going from training to credit is about 79% decline in monthly revenue. The ATE of going from both credit and training to credit is about 1.64 log points decline in monthly revenue, while the ATE of going from both credit and training to training is about 85% decline in monthly revenue. The negative effects of changing the treatments highlights the difference in effectiveness of each treatment in improving the MSEs performance. Further, our ATE results suggest that treating the MSEs with both credit and training improves the MSEs performance better than treating them with only one of the treatment (credit or training); likewise, treating the MSEs with training only would lead to better MSEs performance compared to treating them with only credit.

For those that received credit, the ATT of going from credit to training is not significant. The ATT of going from credit to both credit and training leads to a significant rise in monthly revenue (by 2.268 log points) compared to offering credit alone. This suggests that those that received only credit could have improved their revenue had they received both credit and training. For those that received training, the ATT of going from training to credit is about 21% decline in monthly revenue, though not significant; while the ATT of going from training to both credit and training is about 1.18 log points decline in monthly revenue. Focusing on those MSEs that received both credit and training, providing training decrease the average monthly revenue suggesting that providing training and credit together is more effective than provision of only training in enhancing the performance of MSEs. The result suggests that those that received both training and credit have received effective treatment to improve their performance; since treating them with credit only or training only would have decreased the MSEs performance (see Table 7). In contrast, those that received only credit or only training would have achieved better performance if they have received the joint treatment of credit and training.

Table 7 – ATT estimates of multiple treatments–All

Outcome variable–Monthly sales revenue	**Credit**	**Training**	**Both**
Training vs. Credit	1.054	-0.214	§
Both vs. Credit	2.268 ***	§	-1.188***
Both vs. Training	§	0.924***	-0.956***

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

§These are nonsensical cases to estimate the ATT

Treatment effect heterogeneity by gender

Table 8 presents the heterogeneity in treatment effects based on the gender of the entrepreneurs. In Table 8, we provide the ATE for female and male-owned MSEs sub-sample.[10] In line with our expectation, female and male owned firms benefited differently from the treatments (credit, training and credit-cum-training). As in Sri Lanka and Ghana, access to credit alone does not appear to be enough to improve the performance of MSEs owned by women (Fafchamps et al., 2011; De Mel et al., 2008). Female entrepreneurs do not benefit from any of the treatments, in terms of gain on log of monthly revenue, while male-owned MSEs benefited from all the treatment. Access to credit, training and both credit and training leads to a higher return on monthly revenue of men-owned firms in contrast to not receiving any of these treatments. For credit, training and both (training and credit) male owned beneficiary firms, the actual gain on monthly revenue is about 1.1, 1.2 and 1.8 in log point, respectively; all effects are significant at 1%. It is important to mention that in our context, women-owned MSEs have limited access to all the treatments than their male peers (see table 4). In fact, this is in line with the existing empirical evidence that document that women owned firms have less access to credit than their male counterparts (Asiedu et al., 2013). However, our finding on the treatment effects is in consonance with the finding of Fafchamps et al. (2011) and De Mel et al. (2008) that document no effect of access to credit on profit of female owned firms. Comparing the ATE of a treatment relative to the other treatments by gender of entrepreneurs, we document a negative ATE of training relative to both training and credit for both female and male owned firms. However, considering ATE of the other treatments (credit and both credit and training) versus the other treatments, we find no significant difference in treatment effects.

Two main implications emerges from our results. First, the results clearly highlights the heterogeneous effect of the treatments on women and men owned MSEs and provide insights to policy makers on effective ways of improving the performance of female and male-owned MSEs in the country. Second, the results highlights the complementary nature of the treatments (credit and training) in improving the performance of male owned MSEs. While the female owned firms need either different treatment or another ways of targeting them using the existing interventions.

5 Robustness checks

In this section, we present the treatments effects estimates using propensity score approach for multiple treatments as a robustness check. First, we consider the difference in revenue for receiving a treatment by all entrepreneurs and the comparison group had they received another treatment or being untreated, the ATE. The ATE of receiving credit for all entrepreneurs in comparison to all entrepreneurs being untreated is about 7% increase in revenue per month, though not significant. While the ATE of going from untreated to training and the ATE of going from untreated to both

[10] Due to the fact that ATE is more informative for policy implication by highlighting the effect of the treatments on the general population of male and female owned firms, we focus the discussion on ATE.

Table 8 – ATE of multiple treatments by gender

Outcome variable–Monthly sales revenue	**Female**	**Male**
Credit vs. Untreated	-0.067	1.160***
Training vs Untreated	-0.239	1.215***
Both vs Untreated	0.426	1.889***
	Female	**Male**
Credit vs. Training	0.172	-0.054
Credit vs. both	-0.492	-0.729
Training vs. Both	-0.664*	-0.674*

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

(credit and training) is 1.4 and 2.43 log points increase in revenue per month, respectively. These results confirm that provision of training or a combination of credit and training for the whole MSEs population positively impact the performance of MSEs compared to being untreated (see Table 9). When we compare the relative impact of the different treatments, the ATE of changing treatment leads to a significant decline in monthly revenue. This confirms our earlier finding that highlights the different degree of effectiveness of the treatments.

Table 9 – ATE of multiple treatments–All, using PS

Outcome variable–Monthly sales revenue, ALL - ATE			
Credit vs. Untreated	0.070	Credit vs. Training	-1.376***
Training vs Untreated	1.446***	Credit vs. Both	-2.364***
Both vs Untreated	2.434***	Training vs. Both	-0.988***

$*p < 0.1, * * p < 0.05, * * *p < 0.01$

Table 10 presents the treatment effects of those that received the treatments, ATT, results based on propensity score approach. The ATT results show that only those that received both credit and training are effectively targeted, since their outcome would decline if they receive only credit or only training. While those that received only credit or training only could realize improvement in their performance if they had been treated with both credit and training. Overall, the result highlights the effectiveness of both credit and training in improving the MSEs performance in terms of revenue.

Comparing the treatment effect estimates based on PS and MESR, we find qualitatively similar positive impact of offering treatments (credit, training or credit-cum-training) for the MSEs population in urban Ethiopia. Besides, we find qualitatively similar results of ATE and ATT estimates relative to other treatments that suggest improving the MSEs performance require provision of both credit and training simultaneously.

Table 10 – ATT of multiple treatments–All, using PS

Outcome variable–Monthly sales revenue	Credit	Training	Both
Training vs. Credit	1.714	-0.733**	§
Both vs. Credit	2.380***	§	-1.550***
Both vs. Training	§	1.003***	-0.962

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

6 Conclusion and policy recommendations

In this paper, we evaluate the impact of the provision of credit only, training only or credit-cum-training on MSEs performance and examine if any impact heterogeneity between women and men owned enterprises. The results suggest that provision of credit, training or a combination of credit and training for the MSEs positively impact their performance compared to being untreated. Comparing the relative effectiveness of each treatment for the whole MSEs population, we find receiving both credit and training is the most effective treatment to improve the MSEs performance in terms of revenue. The relative ATT results reveal that those that received either credit only or training only could have improved their MSEs performance had they have received both credit and training simultaneously. This implies that the single treatments (credit only or training only) are not effectively targeted.

Disaggregating the treatment effect by gender, the ATE of the treatments to women owned MSEs is insignificant. On the other hand, access to credit, training and credit and training leads to a higher return on monthly revenue of men-owned firms compared to being untreated. Male entrepreneurs benefited the most from simultaneous access to credit and training. Our results clearly highlight the complementarity nature of the treatments. The finding that the interventions lead to higher monthly revenue indicates that public policies of GoE aiming at improving access to credit, technical assistance or provision of training in MSE sectors should be strengthened. Improving access to treatments should be the first step to improve the performance of female-owned firms. However, the interventions should be fine-tuned to meet the specific needs and demands of enterprises. The results of the treatment effect show that women-owned firms do not benefit from the existing interventions suggests that promoting women entrepreneurship requires more than creating access to credit and/or training. Perhaps, policies that encourage women entrepreneurs to diversify into different sectors such as manufacturing or construction with high returns could have long-lasting effects.

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Appendix A Identification

Estimating the treatment effects is challenging, since the counterfactuals are unobservable. Identification, however, is obtained by untestable assumptions. These are *the common support* and *conditional independence assumption (CIA)*. It is important to understand the implications these assumptions and assess their plausibility in the context of each evaluation study using observational data. Their plausibility depends on the available data and economic questions the study aims to address.

Common Support condition: each individual has a positive probability of receiving each treatment. This implies that there are no values of covariates that could occur only among units receiving one of the treatments. Precisely, there is a sufficient overlap between groups receiving different treatments. Formally, the common support condition is:

$$0 < p(T_i = m|X) < 1 \text{for all } \mathbf{X} \text{ and } m \tag{12}$$

Conditional Independence Assumption (CIA): treatment participation and treatment outcome is independent conditional on a set of observable attributes. This implies that the set of observed covariates $\mathbf{X}$ are sufficiently rich such that it includes all variables directly influencing both T_i and Y_i.

Imbens (2000) show that the multiple treatments version of conditional independence assumption that identifies the parameters of interest. Formally, the CIA is:

$$Y^0, Y^1, \ldots, Y^M \amalg T|\mathbf{X} = x \quad for\ all\ x \tag{13}$$

They also show that properties similar to the propensity score property hold in multiple treatments framework. That is instead of conditioning on the attributes, it is possible to condition on the participation probability (propensity score). Under the two assumptions, we can in principle estimate the treatment effects in Table 2. Empirically, this involves including large set of regressors in the propensity score model thorough review of literature to ensure that the two assumptions are met.

Appendix B Estimating the Propensity Score

There are several approaches to estimate the propensity score in the case of multiple treatments. Lechner (2001) estimates the propensity score using multinomial probit. It is also possible to use multinomial logit or other machine learning methods. This study estimate the propensity score using multinomial logit (MNL). Practically this involves constructing a multinomial treatment variable as dependent variable and estimate a MNL regression of the treatment variable on set of regressors.

Estimating the Weighted Mean of Potential Outcomes for each treatment and Treatment Effects

In order to estimate the treatment effects in Table 2, we need to estimate the means of potential outcomes. A problem in estimating the mean outcomes is the possibility that samples receiving different treatments typically differ in their distribution of covariates that likely also differ in their observed outcomes that are not attributable to treatment. Hence, it is important to ensure that the distribution of covariates for the samples under different treatments is as similar as possible except in the treatment they receive.

An approach for achieving this is to re-weight the treatment sample so that the distributions of covariates match that of any other treatment groups. Several studies (Frölich, 2004; Wooldridge, 2010) show that under CIA and common support, reweighting the treatment sample using the reciprocal of the probability that an individual received the treatment. This approach of weighting to estimate the mean outcome and ultimately the treatment effects is known as inverse probability weight (IPW). Thus, the means of potential outcomes are estimated using inverse probability weighted regression adjustment approach.

To estimate the pairwise ATEs (E.g.,$\mu_t - \mu_{t'}$), consistent estimates of the population means of the potential outcomes for each of the treatments (μ_t and $\mu_{t'}$) is required. Given the propensity score, $p_t(X)$, the probability that an individual with pretreatment characteristics $\mathbf{X}$ receives treatment t ($p_t(X) = pr(T[t] = 1|X)$). A consistent estimate of μ_t is given by the weighted mean in Eq.14, where the weights satisfy $w_i[t] = \frac{1}{p_t(X)}$.

$$\mu_t = \frac{\sum_{i=1}^{n} T_i[t] Y_i w_i[t]}{\sum_{i=1}^{n} T_i[t] w_i[t]} \tag{14}$$

Then, ATE for $\mu_t - \mu_{t'}$ is $\tau_{ate}^{tt'} = \mu_t - \mu_{t'}$.

To estimate the pairwise ATTs for one of the treatments t' (E.g., $\mu_{t',t''} - \mu_{t',t'}$), consistent estimates for the mean of the potential outcomes for MSEs like those who received the treatment t' had they received the other treatment conditions t''. Given the above two assumptions hold, a consistent estimate of $\mu_{t',t''}$ and $\mu_{t',t'}$ will be given, respectively by the weighted and unweighted mean in Equations (15a) and (15b).

$$\mu_{t',t''} = \frac{\sum_{i=1}^{n} T_i[t''] Y_i w_i[t', t'']}{\sum_{i=1}^{n} T_i[t''] w_i[t', t'']} \tag{15a}$$

$$\mu_{t',t'} = \frac{\sum_{i=1}^{n} T_i[t'] Y_i}{\sum_{i=1}^{n} T_i[t']} \tag{15b}$$

The weight in Eq. (15a) is $w_i[t', t''] = \frac{p_{t'}(X)}{p_{t''}(X)}$. Taking the difference between Eq. (15a) and Eq. (15b), we can estimate the ATT for $\mu_{t',t''} - \mu_{t',t'}$ as $\tau_{att}^{t't''} = \mu_{t',t''} - \mu_{t',t'}$.