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Energy Supply Contracting Adoption: Empirical Evidence from the Swiss Market

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Abstract

Energy supply contracting consisting in outsourcing energy-related services is considered as a promising tool to induce investment in energy efficiency and renewable technologies. Yet, energy contracting markets grow slowly and Switzerland is lagging behind. In order to assess whether the potentials are under-exploited, the determinants of energy supply contracting adoption are assessed using a random effects probit model on a dataset of 2,003 accepted and rejected contracts in Switzerland. Results show that the advantages of risk sharing and economies of scale brought by contracting as well as trust towards the supplier and the technology seem determining in the client's choice. The number of interlocutors involved, inducing higher expected adaptation costs, impacts negatively adoption. Less specific contracts involving residential or new buildings are more likely to be signed. The results imply that in order to fully exploit the potentials of contracting, a priority is to clarify to which extent owners can transfer the costs onto the tenants. Information campaigns are still needed to reduce the lack of confidence in energy renewable technologies. This study also provides the suppliers with guidelines to better exploit the market.

JEL Classification: L24, Q40

Keywords: Energy service contracting, ESCo, vertigal integration, transaction costs economics, risk sharing, renewable energy

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1. Introduction

Energy service contracting consists in outsourcing part or all energy-related services to a contractor, the Energy Service Company (ESCO). The supply of these services are guaranteed through long term contracts that can involve the financing, operation and maintenance of the equipment and the provision of heating, cooling or lighting. Since the decisions rights are transferred to the contractor through a long term contract, it gives to the ESCO the incentive and the means to optimize equipment performance (Sorrell (2005)). The literature often refers to two different types of energy contracting: *Energy Supply Contracting* (ESC) and *Energy Performance Contracting* (EPC). ESC covers usually one or more streams of *useful* energy, but the contractor exert no or little control over the demand for *final* energy services. The payment scheme in these contracts often is an indexed unit price for delivered energy plus a fix amount. EPC differs in the fact that the contractor has a control over the demand for final energy services. And because the ESCO is either paid by a share of the energy savings achieved or provides a guarantee on a minimal amount of achieved savings, there is a contractual incentive to reduce energy demand.
In both cases, the client can share some of the risk, reduce his lack of technical knowledge or access to capital, and benefit from economies of scale, market competition and incentives from the ESCO to maintain performance over contractual time. As a result, energy contracting has been considered a promising tool to overcome barriers to energy efficiency (especially through EPC) and renewable energy investments (especially through ESC) (Sorrell (2007), Yik and Lee (2004), Soroye and Nilsson (2010)).

Although energy contracting is seen as an appealing business opportunity as well as an environmental solution (Sorrell (2007)), some have argued that its potentials do not seem to be fully exploited yet, a problem referred to as the *Energy Service Gap* (Backlund and Thollander (2011)). This observation relies on the analysis of general trends characterizing ESCO markets. First, a slow-down is observed in both US and European ESCO markets, which cannot solely be explained by the recent economic crisis (Langlois and Hansen (2012)). Then, transaction costs incurred by these types of contracts imply that they are mostly relevant beyond a certain scale and targeted to specific market segments, leaving behind SMEs and small energy consumers. Untapped potentials are also mentioned in public (Satchwell et al. (2010)) and residential buildings (IEA-RETD (2013)).

The existence of an *Energy Service Gap* is challenged by some authors claiming that the slow-down observed is due to the fact that “low hanging fruits” have already been harvested in most countries, including Switzerland (Marino et al. (2010), Goldman et al. (2005)). Whether the *energy service gap* exists or not calls for an investigation on energy service contracting adoption and underlying barriers and drivers. If the possibilities to grow further and target new market segments exist but are not exploited, then one should review the barriers that are hampering such an expansion. Conversely, if barriers happen to be non existing or unbinding, then this could mean that ESCOs have already exploited the existing market niches. In this case, other instruments than energy contracting, either new business models or public policies, need to be used to promote the deployment of renewable technologies and energy efficiency.

The analysis of energy service contracting adoption is particularly interesting in Switzerland because the government decided in 2011 to progressively phase out nuclear power while ensuring security of electricity supply. Moreover, the Swiss ESCO market is characterized by a slow growth for ESC, and EPC is only emerging (Marino et al. (2010)). The context is adequate to explore whether the ESCO market has already exploited all potentials or is blocked by several barriers. On the other hand, this also implies that EPC data is not sufficient in Switzerland to lead an econometric analysis on probability of adoption. As a result, this study includes data on energy supply contracts only. More specifically, using evidence from an original dataset of 2,003 rejected and accepted ESC projects proposed by two of the largest Swiss ESCOs, from 1996 to 2011, this paper empirically assesses the drivers and barriers of ESC adoption. Although focusing on ESC market, it can still inform on the closely-related EPC framework conditions.

The remainder of the paper is organized as follows: the next section reviews empirical literature on energy contracting adoption and the main contribution of this paper. Then, the theoretical framework upon which energy contracting adoption is based is presented together with a selection of determinants to be tested. The empirical methodology is developed in section 4, followed by a description of the dataset. Results are then presented in section 6, followed by robustness checks and limitations. Section 8 contains general discussion and conclusions.

2. Literature review on energy contracting adoption and contribution

Until very recently, there was no attempt to assess econometrically the determinants of energy service contracting adoption. The recent exception is Polzin et al. (2016), who explore the German municipalities' willingness to adopt EPC using stated preferences collected via a survey. They found evidence that energy performance contracting is an interesting tool for financially and capacity-constrained collectivities. Interestingly, they also show that municipalities tend to underestimate the risk related to retrofitting and therefore do not fully consider the risk-sharing advantage of energy service contracts.

Empirical research in the domain however lacks evidence based on actual contractual choices[1]. This is probably due to the fact that data collection is a complex issue in the ESCO market (Mathew et al. (2005)). First, ESCOs do not always document their projects or have no standardization in the way they archive their contracts. Second, many ESCOs do not easily share the information with researchers due to confidentiality or competitive reasons. As a result, most of the studies make use of descriptive analysis based on interviews and perception of various impacts in order to assess the success factors and barriers of energy service contracting markets. Among these works, several papers have focused on possible barriers (Singer and Lockhart (2002), Bertoldi and Boza-Kiss (2007), Vine (2005), Marino et al. (2010)) while others attempt to evaluate a specific sector, such as SMEs (Backlund and Thollander (2011)). Other studies attempted to evaluate specific obstacles, such as financing (Li (2012)) or critical

[1] An exception of econometric analysis based on actual contracting data is Li et al. (2014). They however focus on the determinants of contractual design and not on energy service contracting adoption.

success factors of the contracts (Xu et al. (2011)). While providing useful insights into the current situation of energy contracting markets, the available studies rarely use econometric analysis based on actual contractual choices and revealed preferences to support their conjectures. This research attempts to fill this gap by using original data on rejected and accepted energy contracting projects in order to empirically assess the determinants of energy service contracting adoption, in an interesting Swiss context. Furthermore, the determinants expected to have an impact on the decision are scrupulously selected and justified by predictions from the economic theory on the choice to externalize or vertically integrate, as described in the next section.

3. Theoretical Background of Energy Contracting Adoption

Few studies attempted to develop a theoretical framework applied to energy contracting. Yik and Lee (2004) and Li et al. (2014) provide models for energy performance contracting viability and design based on net present values of future savings. Sorrell (2007) relies on economic theory, and more specifically on transaction cost economics, to assess contracts' viability, applicable for both energy performance or energy supply contracting. He argues that energy service contracting represents a shift from a hierarchical form of organization (vertical integration) to a more market-based form and thus can reasonably be related to the economic theory of the firm and the 'make-or-buy' decision. Potential savings in production costs and aggregate production costs are key determinants in Sorrell's model to explain contract's viability. Two other factors inspired from the transaction cost economics are added, namely asset specificity and contract's incompleteness. Sorrell's model provides useful insights on the factors that can influence the decision to opt for energy contracting.

The present study follows Sorrell's idea to ground the determinants of ESC adoption into vertical integration theories. It does so by combining the factors predicted by transaction costs economics with risk-sharing (from incentive system theory) and economies of scale considerations, in order to fully explore all the mechanisms susceptible to determine energy service contracting adoption.

3.1. Basic Setup

A customer who wants to acquire an energy service, such as heating, lighting, cooling or aeration faces a multitude of options, with some examples described in Table 1. First she can opt for a totally in-house provision, which can be seen as a vertical integration, where the supplier is an employee such as an energy manager, who takes care of each necessary activity $j = 1, ..., J$ in order to provide energy services. The employee is allocated with a cost-plus compensation scheme $(F_1 + C)$, that is a fixed wage (F_1) and the corresponding amount needed to pay each activity $(C = \sum_j c_j)$. In this case the employee bears none of the cost.

Another possibility for the customer is to adopt a conventional turnkey project, where the supplier is typically a contractor who is paid a fixed price to design, purchase and install the equipment. Then, the customer pays separately a variable cost for the operation and maintenance of the equipment and for the primary energy purchase at the time these activities are needed. In this case the main supplier, i.e. the contractor, bears a larger part of the total production cost, $(z_2 = (c_d + c_p)/C)$, including design and engineering cost (c_d) and purchase and installation cost (c_p).

Finally, the customer can opt for energy supply contracting, where the supplier, i.e. the ESCO, is paid a fixed price to take care of the whole process including operation and maintenance. In addition the customer pays a variable cost corresponding to her energy consumption. In this kind of contractual relationship, the cost share borne by the supplier ($z_3 = (c_d + c_p + c_m)/C$) is the highest, including operation and maintenance costs (c_m). A priori, contracting seems to be very close to a conventional turnkey project, where the only difference in the former is that the maintenance cost is borne by the supplier. However, in practice, this represents an important difference since this provides the ESCO with the incentive and the mean to control and optimize the equipment performance over its entire lifetime[2].

	Totally in-house ($k = 1$)	**Conventional Turnkey Project** ($k = 2$)	**ESC** ($k = 3$)
Suppliers (paid fixed F_k):	**Employee** (F_1)	**Contractor** (F_2)	**ESCO** (F_3)
Energy Service Activities j (incurring variable costs c_j)			
Design & Engineering	c_d		
Purchase & Install	c_p		
Operation & Maintenance	c_m	c_m	
Energy Purchasing	c_e	c_e	c_e
Suppliers' costs share (z_k):	$z_1{=}0$	$z_2{=}\frac{(c_d+c_p)}{C}$	$z_3{=}\frac{(c_d+c_p+c_m)}{C}$
Client's payment:	$F_1 + C$	$F_2 + (1 - z_2)C$	$F_3 + (1 - z_3)C$

Table 1: Options from the energy consumer's point of view

Table 1 does not represent a comprehensive picture of all the alternatives available to a customer to acquire the necessary energy services. Any combination of fixed and variable payments would be a possible option. Thus, the supplier's cost share (z), which can also be seen as an externalization's degree, is considered as a continuous variable that can take any value between 0 and 1. It has been shown that extreme contracts, i.e. totally in-house and full externalization, often prevail in practice for procurement contracts (Bajari and Tadelis (2001)). In the context of energy services however, full externalization with $z = 1$ is unlikely to apply. Indeed, moral hazard typically prevent the contractor to offer a contract with a fixed price for all energy service activities, including primary energy purchase, since she has no complete control over the final energy demand. This could be different, were the contract including both energy performance contracting and energy supply contracting, in which the ESCO would control the whole process of activities to provide energy service, including energy consumption. However to my knowledge, these kind of contracts have never been proposed in Switzerland[3].

[2] or at least during the entire contract's time. Nevertheless, in the majority of the ESC contracts considered in this paper, the contract's time corresponds to the expected lifetime of the equipment.

[3] Integrated Energy Contracting (IEC) is known as being a combination of energy performance contracting and energy supply contracting (Bleyl (2011)). These contracts show a higher degree of externalization but still don't reach an all-inclusive fixed price with $z = 1$. They typically include a quality insurance for energy efficiency and the energy is sold at its marginal cost, in order to prevent the ESCO to have an incentive to supply more energy. A few IEC projects have proven feasibility in Austria.

As a result, a customer's final choice for energy service provision will depend on her optimal choice for z^*, which results in ESC adoption if and only if:

$$z^* \geq z_3 \Leftrightarrow U_{it}(ESC) > U_{it}(other\,provision) \Leftrightarrow y_{it} = 1 \tag{1}$$

where z_3 is the ESCO's cost share ratio, which includes all necessary energy service activities costs except energy purchase[4]. y_{it} takes the value 1 if individual i signs the ESC contract t proposed and zero otherwise.

While the cost share ratio z is determining the customer's optimal choice, it is important to assess the trade-offs inherent to this variable of interest. The following subsections develop the economic theories that underly the decision process in adopting energy supply contracting.

3.2. Transaction Costs Economics: Contract's incompleteness & Specificity

Transaction costs economics (Williamson (1971), Lyons (1996), Gibbons (2005)) leads to observe the energy service provision's choice from the perspective of a trade-off between reducing production costs through energy contracting or mitigating adaptation costs through self-investment (Tadelis and Williamson (2013)). Appendix I provides a formalized simple theoretical model applied to energy supply contracting adoption, which is rooted in transaction costs economics. In this model, the consumer's optimal choice, and consequently the adoption of energy contracting, depends on the probability that these adaptation costs are incurred and their expected magnitude.

The production costs represent the total costs for all the activities necessary to provide the energy service[5], i.e. $C = \sum_j c_j$ in Table 1. The supplier choses an amount of effort, presumably unobservable to the client, represented for instance by the quality of the equipment or the time spent to look for the most adapted technology. The supplier's first order condition implies that the level of effort is increasing in z. Thus, a relatively higher supplier's cost share, as is the case with energy supply contracting, provides him with an incentive to increase effort and hence, reduces production costs.

This result, however, must be outweighed by the fact that z is also assumed to increase ex post adaptation costs[6] in case an exogenous disturbance occurs. Adaptation costs are represented by renegotiation and litigation costs, eventual legal expenses and possibly all the costs related to a modification of the technology or a transfer to another client or supplier. The disturbances in ESC could typically be technical problems, financial issues on either the client's or the supplier's side or a change in the client's behavior or use. The assumption that adaptation costs are larger under ESC can first be motivated by the fact that the larger the cost share borne by the supplier, the more she can gain from haggling, engaging in opportunistic behavior or negotiation and as such, the stronger incentive to

[4] Since a higher degree of externalization than z_3 is observed neither in this sample or in Switzerland, the choice can without loss of generality been simplified to opting for ESC if and only if $z^* = z_3$.

[5] These activities can include audit, design and engineering, purchase and installation of technical appliances, operation and maintenance during the whole technology lifetime and purchase of primary energy.

[6] As opposed to incentive system theory or property-rights theory, which focus on *ex ante* optimal incentive to invest in specific assets, in transaction cost economics the main determinant of decisions concerning the organizational forms of transactions are determined by *ex post* adaptation

do so. Second, when z is large, it consequently means that the buyer has much less flexibility since she cannot control and adapt the cost she pays at each stage of the energy service provision process.
As a result, the optimal choice of z^* depend on the relative importance of adaptation costs mitigation (via a reduction in z) over production costs reduction (via an increase in z). This in turn is determined by the expected magnitude and the probability of occurrence of adaptation costs. This probability is represented in the model as a combination of two key elements. First, contract's incompleteness corresponds to the probability that the contract will be renegotiated due to a disturbance. Second, asset specificity is the probability that the supplier (or the buyer) cannot be replaced by a competitor when disturbance occurs. The necessity of these two components is motivated in what follows.

3.2.1. Contract's incompleteness

If the contract is complete in the sense that it accounts for any possible future contingency and predicts what should be done in each specific case, then there is nor room either need for any renegotiation, reducing to zero the expected adaptation costs. Of course, when the task is complex, as in ESC involving long term contracts and innovative technologies, it is unfeasible or too costly to write fully complete contracts[7].

3.2.2. Specificity

If it is costless to find another client and/or another supplier in case of haggling, then a disturbance does not incur any adaptation cost since it is sufficient for the aggrieved party to step out and find another interlocutor. In reality, however, it is rarely costless for either party to replace her contractual partner and this dependency relies on the degree of specificity of the asset implemented to provide the energy service. Specificity in energy service contracting can take various forms such as site specificity, physical asset specificity and human asset specificity (Sorrell (2007)).
Site specificity relates first to the location of the asset and the level of difficulty to relocate it in case of hurdle.
Then, physical asset specificity represents the level of specialized equipment required by the client and the related importance of auditing, engineering and designing effort before the implementation (Sorrell (2007)). The third form of specificity, i.e. human asset specificity, is closely related to the latter. Indeed, it represents the degree of expertize and knowledge required to implement the equipment and it is likely to be strongly positively related to physical asset specificity. Together, if the two latter forms of specificities are high, they imply on the one hand an important investment for the supplier, which could become a sunk cost if the contract is not concluded or prematurely forced to end by the client. On the other hand, if the supplier does not deliver on its mandate after the contract signature, it may be costly for the client to find another supplier with the adequate level of expertise to take over the exploitation of the specific asset. In either case, a high bilateral dependency between the two

[7] This raises the problematic that *ex post* adaptation costs may be traded off with *ex ante* design costs. Bajari and Tadelis (2001) develop a model where the buyer can endogenously choose the degree of design completeness. They show that the later is monotonously non-increasing in exogenous task complexity. This does not mean that, *ceteris paribus*, in case of very high task complexity the buyer will put no effort in trying to define additional possible contingencies in the contract. But even if she does provide this effort, the design will be weakly less complete. With regard to this result, I focus only on *ex post* adaptation costs and treat contract's incompleteness as an exogenous variable, as in Tadelis and Williamson (2013)

parties exists.
As a result, projects involving a high degree of specificity combined with contract's incompleteness are less likely to be undertaken via energy supply contracting.

3.3. Incentive system theory: Risk sharing

The incentive system theory and moral hazard models (Holmstrom and Milgrom (1991), Holmstrom (1999)) rely on principal-agent analysis to explain the trade-offs underlying the optimal choice z^*. As in the model of transaction costs economics of Tadelis and Williamson (2013), increasing the supplier's cost share z allows to address moral hazard and raises the supplier's unobservable amount of effort in reducing production costs. As a matter of fact, the formalized model developed by McAfee and McMillan (1986) rooted in a principal-agent analysis leads to the same supplier's first order condition as in the simple model of transaction costs economics I develop in appendix I (see equation 8). The difference however lies in the fact that, as opposed to trading off the effort-incentive with adaptation costs mitigation, it does so with risk sharing. Indeed, increasing z not only increases the supplier's cost share, but also its risk share. Assuming the agent (in our case potential suppliers) are more risk averse than the principal (in our case the client), the moral-hazard model predicts that as the level of risk increases, so does the agent's need for insurance, making in-house projects more desirable than externalization[8]. In this model, the element that matters the most is the risk borne by the agent, who is the ESCO in our case. Other determinants, such as the efforts and risk aversion of both the principal and the agent, are assumed to have an effect on the optimal choice z^*. Unfortunately, these do not easily lend themselves to empirical assessment. This is why this study primarily focus on the level of risk borne by the ESCO, and its assumed negative impact on energy contracting adoption.

3.4. Economies of scale

Economies of scale are not directly considered in the basic models of transaction costs and incentive system theories. Indeed, the total production costs the customer is paying for energy services, $F + (1 - z)C$, does not enter into the optimal choice z^*. As such, it is therefore expected to have no impact on ESC's adoption, contradicting Sorrell's (2007) assumption on the impact of this variable. Indeed, the hypothesis raised by Sorrell (2007) is that the aggregate production costs for energy service in the client organization should have an inverted-U impact on energy contracting's suitability. This is explained by the fact that for small clients, adaptation costs may be hardly supportable and outweigh the gain in production costs. Thus, ESC would not be suitable under a certain threshold[9]. Once this threshold reached, small size energy consumers will gain from economies of scale brought by the ESCO. At the end, very large clients may benefit less from ESC as opposed to in-house energy management in terms of gain in production costs.

3.5. Other determinants

Contract's incompleteness, specificity, risk and economies of scale are assumed to be the main determinants in the client's choice to opt for energy supply contracting. Other elements from transaction

[8] see for instance the model developed in McAfee and McMillan (1986) or Lafontaine and Slade (2007)
[9] This hypothesis could be accounted in the model of Appendix I by relaxing the assumption $v - K(z) > 0$. That is, the energy service's value is not always worth risking *ex post* adaptation costs.

cost economics, incentive system theory and from other theories related to the make-or-buy decision[10] could potentially have an impact on ESC adoption. For instance, McAfee and McMillan (1986) introduce in their incentive-system model a bidding competition effect making a high z (i.e. externalization) less desirable since it also decreases *ex ante* bidding competition[11]. The ease to specify quality and service could also be an important factor in the decision to opt for energy contracting, since this can be related to the model of bundling the construction with the operation and maintenance phase developed by Hart (2003) in the context of public private partnerships. Other theories, such as property-rights models (Grossman and Hart (1986), Hart and Moore (1990)) could also bring other interesting conjectures in this context. Property-rights theory focus on *ex ante* decisions on investment incentives and how they are determined by the allocation of asset ownership. As opposed to transaction costs economics, asset specificity only matter in the decision if it affects the marginal returns on investments. The interest of exploring these conjectures in the context of ESC adoption is not questioned. Nevertheless, because these predictions are difficult to test empirically, especially with these data[12], they cannot be tested. They may however prove to be useful in the interpretation of this paper's results.

4. Empirical Methodology

An energy service customer ($i = 1, ..., n$) can either decide to sign the energy supply contracting (ESC) offer ($t = 1, ..., T_i$) proposed, to ask for another bid $t+1$ or to choose an outside option[13]. Customer i's choice is supported by a comparison of the utility acquired with the ESC project t proposed, $U_{it}(ESC)$, and the outside option's utility, normalized to zero. Therefore, the customer will opt for the contract t if and only if $U_{it}(ESC) > 0$. The binary variable $y_{it} = \mathbf{1}[U_{it}(ESC) > 0]$ is observed.

$$\begin{aligned} U_{it}(ESC) = & \alpha + \beta_1 oil\_backup_{it} + \beta_2 canton\_ESCO_{it} + \beta_3 \ln(duration_{it}) \\ & + \beta_4 technology\_specificity_{it} + \beta_5 new\_building_{it} + \beta_6 residential_{it} \\ & + \beta_7 intermediary_{it} + \beta_8 rented_{it} \\ & + \beta_9 interest\_rate_{it} \\ & + \beta_{10} \ln(TC/year)_{it} \\ & + \beta_{11} surface_{it} + \beta_{12}^{'} year\_dummies_{it} + u_i + \epsilon_{it} \end{aligned} \tag{2}$$

[10]See Gibbons (2005) for a formalization of the theories that could be taken into account

[11]Except from the case with $z = 0$, the suppliers' bids reveal their privately observed expected costs and therefore their efficiency. An increase in z has an effect similar to an increased variance between competitors' costs and results in smaller possibility and incentive to compete. When z is small on the other hand, the suppliers are more able to ignore their costs when bidding, increasing therefore competition.

[12]Property ownership, for instance, does not vary in this dataset: when providing ESC, the ESCO always keeps the asset ownership during the entire contract's duration. Also, no information exists on the bidding firms at the time the offers are proposed to test McAfee and McMillan (1986) predictions. Finally, since the offers of only 2 ESCOs are represented in this sample, quality and service specifications do not vary sufficiently to test the interesting predictions from Hart (2003).

[13]Unfortunately, while it is known when an offer has been or not rejected, the outside option is unknown. In some cases, the customer might have chosen an ESC contract of another bidder, in which case, the choice does not necessarily include the trade-offs developed in the last section. However, it is assumed here that in general the customer will choose a less comprehensive energy service (i.e. a smaller z, than under ESC) when rejecting an ESC offer. This assumption is supported by the fact that conventional turnkey projects are much more frequent in practice than ESC.

The choice of explanatory variables is supported by the theories developed in section 3, i.e. transaction costs economics (for variables attached to coefficients β_1 to β_8 in equation 2), incentive system theory (attached to coefficient β_9), economies of scale (coefficient β_{10}), while the last line of the equation includes controls, random effects and the error term. Table 2 relates each covariate (*variable name* in column 4) with the corresponding theoretical determinant developed in section 3 and listed in column (1). Column (2) presents the elements assumed to have a linear impact on the theoretical determinants and further explained in the following subsections. Finally, column (3) shows the predicted direction of the effect of these elements and their proxies on the probability to adopt energy supply contracting.

(1)	(2)	(3)	(4)
Determinant	Influenced by	predicted impact on adoption	proxy for empirical testing (*variable name*)
Transaction Cost Economics			
contract's incompleteness	trust in technology	positive	heating system with oil as backup (*oil_backup*)
	trust in ESCO	positive	same canton as ESCO (*canton_ESCO*)
	duration	negative	contract's duration ($\ln(duration)$)
physical & human asset specificity	technology specificity	negative	one minus the share of this technology in all building types in Switzerland that year (*technology_specificity*)
	building flexibility	positive	new building (*new_building*)
site specificity	probability to find another client	positive	residential building (*residential*)
expected adaptation costs	number of interlocutors	negative	intermediary client (*intermediary*)
		negative	rented building (*rented*)
Incentive System Theory			
risk on ESCO	ESCO's ex ante perception of the project's risk	negative	nominal interest rate set by the ESCO and used to compute annuities (*interest_rate*)
Economies of scale			
size and energy intensity of the client	client's total costs for energy services	inverted U-shape	yearly total energy costs for services in contract ($\ln(TC/year)$)

Table 2: ESC adoption determinants & empirical strategy

4.1. Contract's incompleteness

Contract's incompleteness, which affects negatively energy contracting adoption, is expected to increase with the contract's duration ($\ln(duration)$[14]) because the longer the contract, the more difficult it is to contractually account for all contingencies that could occur in the long run.

Conversely, since it is the expected adaptation costs that matter at the time the client decides to opt

[14] the natural logarithm is taken to mitigate the impact of extremely large values (see Data description section)

for contracting or not, it is assumed that trust in the technology and in the ESCO (respectively the client), may work as a substitute for contract's completeness. It can in fact be argued that the more trustful the relationship, the less important the necessity to build a complete contract *ex ante*. Thus, trust is expected to have a positive impact on ESC adoption via a lower need for contract completeness, and consequently lower expected adaptation costs. As can be seen in column 4, two proxies for trust are used, to account for both confidence in the technology and in the ESCO. In some offers, the clients have asked to keep an oil heating system, beside the new technology, to work as a back up. A dummy oil_backup_{it} equating to 1 if oil backup is included in the offer will work as a measure for confidence (respectively non-confidence) in oil heating systems (respectively the new technology proposed). Trust in the ESCO will be measured by the proximity to the ESCO's headquarter, and more specifically, by a dummy which is equal to one, when the customer lies in the same canton as the supplier. This is supported by the fact that the ESCOs in this sample are also electricity utilities, which have been supplying electricity (and possibly other energy or water services) to the customers lying in the same cantons[15]. Therefore, a trustful relationship supposedly already exists between the ESCO and the clients of the same canton.

4.2. Specificity

Physical and human asset specificity arise from the degree of equipment specialization demanded by the client and either dictated by her preferences and/or stemmed from her building's constraints and opportunities (e.g. building's space and interior layout, proximity and access to potential energy sources such as groundwater or lake for heat pumps). A higher technology specificity will increase the bilateral dependency between the two parties since it corresponds to a higher effort in auditing, engineering and design for the ESCO and also a smaller probability for the client to find another supplier in case of haggling with the initial ESCO. The variable *technology_specificity* is proxied using data on space and water heating systems of existing buildings in Switzerland (OFS (2015)). The proxy is computed as the complement to the share of the Swiss buildings having the same technology as the one proposed in the offer in that period of time t[16]:

$$specificity_{it} = \left[1 - \frac{\sum_{b=1}^{B} \tau_{bit}}{B_t}\right] \cdot 100 \tag{3}$$

where B_t is the total number of buildings in the OFS (2015) dataset at period t and τ_{bit} is a technology dummy variable which is equal to one when it is the same technology as the one offered to client i in period t (either for heating and/or hot water) and is also used in the b's building of the census[17].
Asset specificity may also be determined by the flexibility or the constraints brought by the building's layout and environment. For instance, the constraints on the technology is weaker when the building is new, i.e. designed at the same time as the energy equipment (as it is measure by the dummy *new*

[15] Since the liberalization of the Swiss electricity market for large electricity consumers (>100,000 kWh/year) in 2009, some of them may have chosen other electricity providers.

[16] The buildings census is available in 1990, 2000, 2009-2014. Thus, data from the 2000 census was used for offers from years 1996-2004 and 2009 census for years 2005-2009

[17] $\sum_{b=1}^{B} \tau_{bit}$ thus represents the total number of existing buildings using technology τ in period t.

building[18]). On the other hand, when the building has already been constructed, the existing space or interior layout may restrict the types of technology installed.

Site specificity relates to the level of difficulty to relocate the asset in case of hurdle. This matters in case the client moves out or goes bankrupt. Nevertheless, it appears that in practice the ESCOs are more inclined to search for another client to take over the building together with its equipment rather than relocate the installation, regardless of the technology. As a result, site specificity is more likely to be determined by the probability to find a client ready to take over the energy technology rather than by the technology itself. This explains why the technology may not be a good proxy for site specificity. The relative ease to find a new client, however, may be measured by the building type, which allows to mitigate the impact of site specificity. For instance, when the building is used for residential purposes (as represented in the dummy *residential*), it is likely the case that even though the client moves out or goes bankrupt, another resident will take place in the building, reuse the energy technology and thus take over the ESC contract. On the opposite, when the energy technology involves industrial processes, or when the building is used for other purposes than residency, it can be harder to find a substitute client. Even in the case someone is ready to take over the contract, she may not use the energy technology in the same manner, implying larger adaptation costs than in residential buildings.

4.3. Expected adaptation costs

As described in the model of appendix I, the magnitude of expected adaptation costs has also an impact on ESC adoption. This magnitude is likely to be positively impacted by the number of players involved in the ESC contract. Indeed, in case a disturbance occurs, renegotiation and adaptation are expected to be more costly when several actors have interests at stake. This is the case, for instance, when the client is an intermediary (represented by the dummy variable *intermediary*), such as an architect, a general contractor or a real estate investor, whose goal is either to sell the building together with the ESC contract or to rent it.

Adaptation costs, if they occur, are expected to be even larger when the building is rented because the transfer of the costs of ESC onto the tenants involves a risk of legal disputes[19]. As a result, the dummy variable *rented* is expected to have a strong negative impact on the probability to sign the contract.

4.4. Risk on ESCO

In the context of energy supply contracting, the risk borne by the ESCO is the technical risk (e.g. unpredictable costs arising in the construction phase of the project or any technological default occurring over the contract's duration), the financial risk (e.g. client's relocation, change in behavior, or bankruptcy) and the risk of litigation and renegotiation in the contract's course. The ESCO will consequently assess the risk *ex ante* and incorporate its risk premium into its bid, and more precisely via the nominal interest rate that is set to compute the annuities. Data information on the interest rate has directly been collected from the ESCO. The interest rate is set by the ESCO as an initial

[18]the dummy equates one if the technology of the ESC contract is installed at the same time the building is constructed.
[19]The risk of legal disputes is related to the transfer of the costs onto the tenants. See discussion in the results section for more on this.

value which depends on characteristics of the client and the project. It is argued here that the nominal interest rate is positively affected by the ESCO's *ex ante* risk assessment of the project and therefore is an adequate proxy for the risk perceived by the ESCO.

4.5. Aggregate production costs and controls

Finally, the impact of aggregate production costs of energy services[20] $s = 1, ..., S_i$ will be tested using the following proxy:

$$\frac{TC}{year} = \sum_{s}^{S_i} (P_s \cdot consumption_s) + FC + \frac{client\_initial\_financing}{duration} \tag{4}$$

First, it includes the variable cost, which is the yearly consumption of each energy service multiplied by the corresponding price of primary energy. Each customer is assumed to consume at least heating and hot water, and when specified in the ESC contract, it can include other energy services as well, such as ventilation, cooling, etc. When primary energy purchase is not included in the contract, and thus no price is specified, an approximation of the market price[21] of the primary energy is used to specify P_s. The yearly fixed cost, FC, typically includes the amortization of the investment financed by the ESCO, the design, the operation and the maintenance. Finally, in some contracts, the client participates to the initial financing by an amount represented by $client\_initial\_financing$. Simply dividing it by the contract duration allows to account for this participation in the yearly total cost the client is paying to acquire energy services. Aggregate production costs is expressed in logs in order to mitigate the effect of outliers.

Finally, $surface\_it$ represent the squared meters surface of each client's building and allows to control for scale effects and $year\_dummies_{it}$ for unobserved external factors specific to each year.

4.6. Estimation method

Because each client is facing one or several offers which she can either decide to reject or accept, the dataset is treated as an unbalanced panel. The estimation method selected is a random effects probit model, where idiosyncratic errors, independent across offers and individuals, are assumed to follow a standard normal distribution ($\epsilon_{it} \sim N(0, 1)$) and $u_i \sim N(0, \sigma_u^2)$ are the offer-invariant random effects, assumed to be unrelated with the regressors and independent across individuals.
As opposed to a pooled estimation, random effects allow the disturbances $v_{it} = u_i + \epsilon_{it}$ to be correlated within an individual. This implies that the Log-Likelihood function is a T-fold integral computationally challenging. The solution used here is the Gaussian quadrature with Hermite integration formula suggested by Butler and Moffitt (1982). In addition, project-cluster robust standard errors are used to

[20] The aggregate production costs include primary energy purchase even if it is not included in the ESC contract.

[21] ElCom (2014), Surveillant des prix (2014) and OFS (2016) data on monthly or yearly energy prices are used for the estimation of primary energy prices, and depend on either the month or the year of the offer and the size of energy consumption per year. When primary energy is electricity and data is available, the electric supplier and the kind of technology (i.e. of heat pump) has also an influence on the variable cost. Following Phillips (2010), I assumed geothermal, groundwater and lake-water heat pumps use 35% of primary energy and air-water heat pump 25%.

allow for correlation within the same project[22]. In order to evaluate the magnitude of the impact of each variable on the probability to sign the ESC contract, the average marginal effects of each variable on the prediction that $y_{it} = 1$ are computed using the estimated random effects for each client[23].

5. Data description

The empirical analysis relies on a unique dataset containing 2,003 rejected and accepted ESC projects between 1996 and 2011 from two of the largest Swiss ESC providers[24]. As can be seen in Figure 1 and Table 3, except from a peak in 2001[25], the adoption is quite low, with on average 28% offers accepted in the sample.

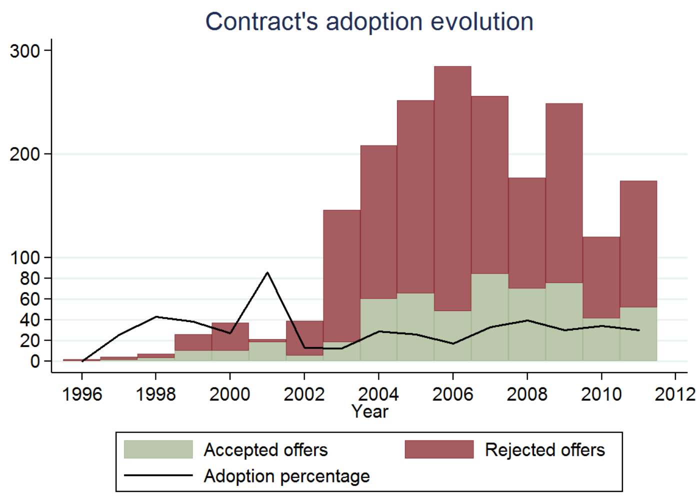

Figure 1

	Number	%
Rejected offers	1,443	72
Accepted offers	560	28
Total	2,003	100

Table 3: Offers

There has been 1 to 8 offers proposed to each client. Table 4 provides descriptives statistics of the cost components that are presented in these offers and of the total energy cost for each client. Each offer includes typically an annual fixed cost covering capital, operation and maintenance costs and a variable cost for primary energy purchase which depends on the client's energy consumption. When the client participates to the initial financing, the fixed cost is consequently reduced. This explains

[22]The number of projects is smaller than the number of potential clients because it can happen that several clients, each with several offers, take part of the same project.

[23]these results will be compared with the average marginal effects obtained when assuming $u_i = 0$, i.e. the random effects are equal to zero.

[24]Initially, 2,506 offers were collected, including as well the time period up until 2013. Since some 2012 projects were still under negotiation at the end of the data collection, it was not possible to conclude whether the offers were rejected or not. Therefore, contracts from 2012 on are excluded from the analysis. Because the variables *interest rate*, *ln(TC/year)* and *surface* suffer from a large number of missing values, equation 2 is also estimated without them, resulting in the sample of 2,003 observations. The descriptive statistics shown in this section are based on the latter sample.

[25]During that year, only 21 offers appear in the sample, with 18 of them accepted, suggesting offers meticulously targeted in that year

Variable		Mean	Std. Dev.	Min.	Max.	N
energy costs						
fixed cost	(CHF/year)	31,988	67,516	0	992,906	2,002
client's initial financing	(CHF)	16,355	293,342	0	6,910,000	2,002
price heating	(CHF/kWh)	0.06	0.02	0.02	0.34	1,999
heating consumption	(kWh/year)	178,817	392,991	7,955	7,000,000	1,719
price hot water	(CHF/kWh)	0.07	0.02	0.02	0.28	1,959
hot water consumption	(kWh/year)	65,505	110,717	2,000	2,045,120	1,351
variable cost other cons.	(CHF/year)	469	5,955	0	180,990	2,003
TC/year						
yearly total cost (TC/year)	(CHF/year)	51,153	100,138	32,901	1,983,200	1,577
ln(TC/year)		10.23	1.04	8.1	14.5	1,577
size						
surface per client	(m^2)	32,678	7,910	105	190,000	1,608

Table 4: Scale determinants: total energy costs & size

why the fixed cost's minimal value is zero, which corresponds to the case when the client finances totally the initial investment and that operation and maintenance is accounted for in the variable cost. The variable cost is usually determined by the price in CHF/kWh for each energy service (e.g. heating, hot water, ventilation, etc.) multiplied by the annual consumption of that service (kWh/year). The heating and hot water consumption amounts described in table 4 are the consumptions estimated before the contract is implemented. The price for heating and hot water include both ESC contractual prices and estimation of the primary energy price, when primary energy purchase is not included in the contract. The variable cost for other energy services consumptions (variable cost other cons.), can include ventilation, cooling, passive cooling or other energy services' costs. The variable $\ln(TC/year)$ is computed as described in equation 4 and is used to measure each client's aggregate production cost of energy services.

The statistics show first that the projects are relatively heterogeneous in costs and size. Taking the natural logarithm of yearly total costs mitigates the impact of outliers and the large heterogeneity in the size of the projects. Second, consumption for heating or hot water as well as the variable surface suffer from a large number of missing values. This is why other determinants will also be estimated without these as controls.

Table 5 provides summary statistics of the determinants of risk, contract's incompleteness, specificity and expected adaptation costs.

The proxy for the risk borne by the supplier, ranging from 3.9 to 5.4 %, is the nominal interest rate set by the ESCO as a starting computational value for the different costs applied to each client depending on her type's, building's characteristics and size. This information is available for 674 offers. Other factors will be estimated also without this explanatory variable to circumvent the consequent decrease in sample size[26].

[26] One could think that the missing values issue could be solved using a computation of nominal interest rate with the realization costs and the fixed costs as annuities. This solution has been tested but the computed values differ considerably with the rate set by the ESCO. This is due to the fact that the ESCO's computation of the fixed costs is

Variable		Mean	Std. Dev.	Min.	Max.	N
ESCO's risk proxy						
nominal interest rate	%	5.27	0.25	3.90	5.40	674
contract's incompleteness						
oil backup	dummy	0.05	0.21	0	1	2,003
canton of the ESCO	dummy	0.82	0.38	0	1	2,003
duration	years	26.54	6.31	10	60	2,003
ln(duration)		3.24	0.29	2.3	4.09	2,003
specificity determinants						
technology specificity	%	93.19	3.58	38.22	99.99	2,003
residential	dummy	0.93	0.26	0	1	2,003
new building	dummy	0.83	0.38	0	1	2,003
expected adaptation costs						
rented	dummy	0.81	0.39	0	1	2,003
intermediary client	dummy	0.47	0.5	0	1	2,003

Table 5: Specificity, contract's incompleteness determinants and risk proxy

About 5% of the projects proposed were using oil as a backup technology and a majority of the offers (82%) are proposed to a client within the same canton as the ESCO. While the average contract lasts more than 26 years, a large majority of offers are either 30 years or 15 years contracts. Because only a few offers represent longer period contracts, such as 60 years[27], the distribution of the duration variable is highly skewed to the right. Taking the natural logarithm is supported by the need to mitigate the impact of these outliers. Residential and new buildings are targeted in a large majority of the offers. This suggests that the barriers mentioned earlier for old and non-residential buildings already imply an *ex ante* selection. This selection does not happen on the contrary for rented building (and also to a lesser extent for intermediary clients) since they represent 81% (resp. 47%) of the offers.

	not rented	**all or partly rented**	**Total**
rejected offer	184(49%)	1,259(77%)	1,443
accepted offer	194(51%)	366(23%)	560
Total	378	1,625	2,003
	direct client	**intermed. client**	**Total**
rejected offer	655 (62%)	788 (83%)	1,443
accepted offer	398 (38%)	162 (17%)	560
Total	1,053	950	2,003

Table 6: Interlocutors involved (tenants & intermediaries)

Table 6 nevertheless shows that a higher share of rejected offers occurs when the building is either completely or partly rented (77%) and when the client is an intermediary (83%), a priori confirming

more complex than computing annuities from realization cost and interest rate. It includes for instance discounts made on a case by case basis or subsidies expectations, and the capital costs considered for annuities include only certain realization costs and does not correspond to the one collected in this dataset. Therefore, it can be argued that computed interest rate would represent a poor risk proxy as compared to the one determined by the ESCO.

[27] with only 2 offers

the predictions of last section on higher expected adaptations costs due to more interlocutors involved. This leads to an interesting question: why these two ESCOs continue to target rented buildings and intermediary clients when these represent a large share of failure? Table 7 shows that the reason why so many rented buildings are targeted is because the ESCOs target residential buildings and especially multi-family houses, which are made of a majority (85% in this sample) of rented housing (as it is typically the case in Swiss residential buildings[28]). This raises a dilemma: Targeting residential buildings increases the probability for the ESCO to find another client in case of disturbance but this often comes at the cost for the owner of an increased risk of legal disputes with tenants.

	not rented	**all or partly rented**	**Total**
not residential	100(68%)	46(32%)	146
residential	278(15%)	1579 (85%)	1857
Total	378	1,625	2,003
	direct client	**intermed. client**	**Total**
old building	292 (84%)	56 (16%)	348
new building	761 (46%)	894 (54%)	1655
Total	1,053	950	2,003

Table 7: rented vs. residential / intermediary vs. new

The same kind of dilemma occurs with intermediary clients. The fact that almost half of the targeted clients are intermediary could be explained by the fact that ESC is mostly targeting new buildings, at least in this sample. And the primary interlocutors for new buildings in this sample are at 54% architects or general contractors. As a result, while providing more flexibility for the technology to be installed, new buildings also involve more interlocutors and increase expected adaptation costs. The comparison of the impacts of these variables on the probability to opt for ESC in the next section will provide some interesting guidelines on these two dilemmas.

The minimal value for technology specificity is 38.22% (cf. table 5), which corresponds to one observation with an oil heating system. Figure 2 investigates further the percentage each technology for heating and hot water appears in the sample, as compared with the shares in the Swiss real estate. The proxy for technology specificity, i.e. the complements to the technologies' shares in Switzerland, is then illustrated in the third graph[29]. Heat pumps (HP) (mostly geothermal) are largely predominant in the sample with 88% of the offers. District heating is following with a share of 9% of the sample. Wood, either woodchips or pellets, represents a share of 7.3%. Oil, which is mostly used as a backup for another technology, is present in 5% of the cases, while gas represents a share of 2.5% and solar panels of 1.9%[30].

[28] According to the federal census of the population from the Swiss federal statitics office, 66% of the Swiss housing were rented in 2000.

[29] For illustration reasons, this graph is not a comprehensive figure of all the degrees of specificity in the dataset. Each energetic agent is in fact taken individually in this figure, while the observations of the datasets often combines several energetic agents where each combination has its respective degree of technology specificity.

[30] These numbers are the percentage of occurrence in non-mutually exclusive groups. Since many projects combine several technologies, the total is more than 100%.

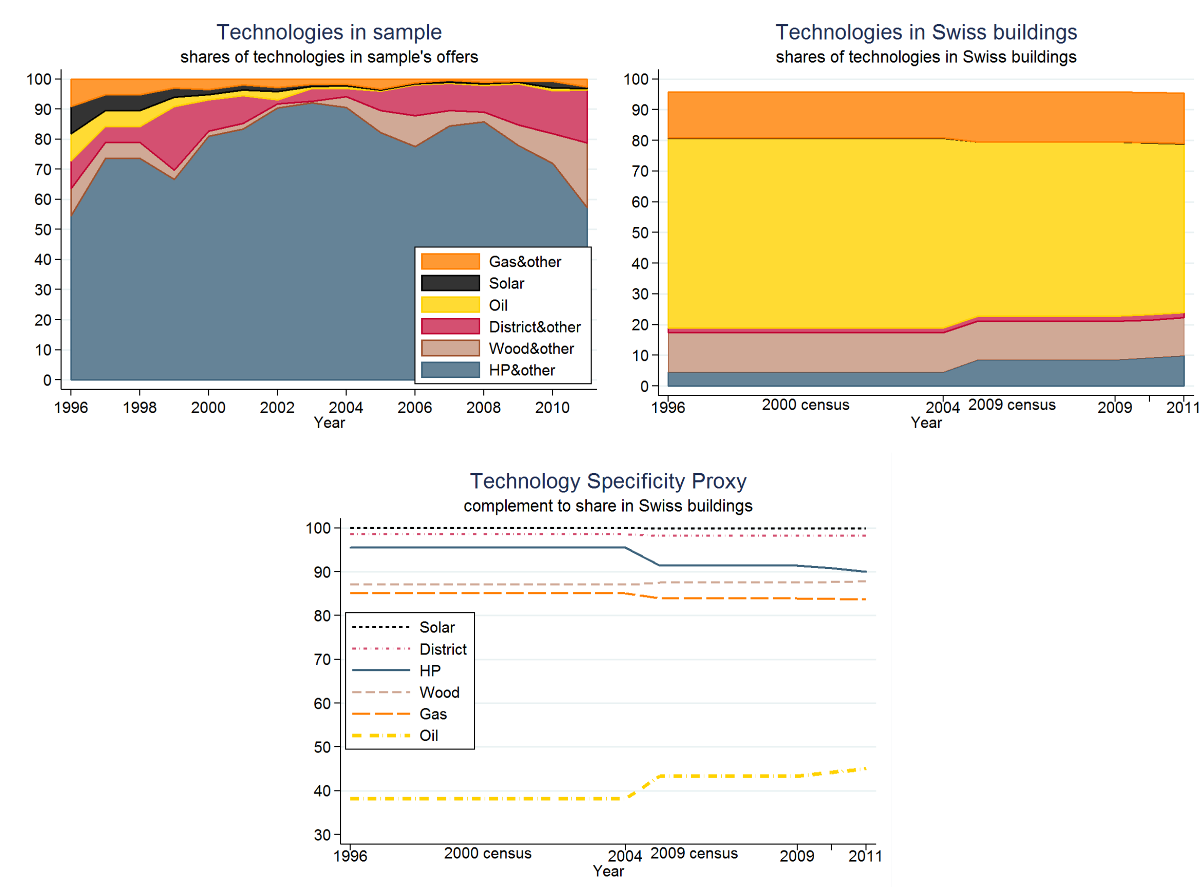

Figure 2

These graphs also show that the technologies most often proposed by the ESCOs are very specific as compared to the one implemented in the existing Swiss real estate at the same time period. This translates in a mean of 93.19% for the variable technology specificity, with 245 offers with a specificity above 99%[31]. One can note that the technology specificity proxy is quite stable through the different census[32]: oil and wood heating systems are becoming slightly less frequent since 2005 —with a corresponding increase in technology specificity— while the technology specificity of heat pumps, gas (and district heating to a lesser extent) decreases slightly since then. Solar shows also a very small decrease in specificity since 2009, probably following the introduction of the costing price retribution in may 2008 (BFE (2008)).

Several innovative technologies are present in the sample, such as groundwater heat pumps (3.2%), lake-water heat pumps (1.4%), air heat pumps (0.9%), and other technologies such as co-generation

[31] This is the case typically for projects combining several types of innovative technologies, such as co-generation and heat pumps, or solar and district heating

[32] As aforementioned, technology specificity variable uses the 2000 census for 1996 to 2004 offers, the 2009 census for 2005-2009 offers and yearly census for 2010 and 2011 offers.

(01%) or residual heat pumps (0.1%). These ratios, together with figure 2 suggest that renewable energy is promoted in energy supply contracts, where fossil fuels such as oil are mostly used only as backup and gas represents a relatively small share. It is worth comparing these with the energetic agents used before the ESC project, in case the building was already existing. From the observations including information[33] on the technology used before the ESC project, 93.4% were using oil, 3.5% electricity, and 3% gas. To some extent, this observation also confirms the conjecture that ESC promotes the investment in renewable energy technologies.

Finally, it is worth describing the characteristics of the buildings and clients targeted by the ESCOs in the sample[34]. Multi-family houses, with 75% of the offers, are largely predominant as a building type. Together with the single-family houses, they are present in 95% of the observations[35]. Shops (5.7%) follow and the remainder is shared between hospital and nursing homes (1.5%), office buildings (2%), hotels and restaurants (1.8%), schools (1.3%) and industrial buildings (1.5%). It is quite interesting to compare these with the buildings typically targeted by energy performance contracting (EPC) projects, which are represented by the so-called public "MUSH" market (municipal and state government, universities and colleges, schools and hospitals). EPC also targets large energetically-complex building types, such as industrial buildings or hotels. On the opposite, residential buildings are only targeted by EPC when they are large and old, with high energy savings potentials (Satchwell et al. (2010)). This suggests that ESC and EPC do not target the same type of buildings.
Concerning clients' characteristics, 44% of them are architects and general contractors. Then, 40% are private owners and 15% real estate investors or investment funds. Firms (6.6%) and public collectivities (3%) represent a small share of clients.

6. Estimation results

The estimation results of equation 2 are given in column 1 of table 8. Due to the small sample size resulting from missing values for the interest rate and total cost per year, the regression in column 2 omit these variables to explore the results in the larger sample of 2,003 observations[36].
The coefficient of contract's duration shows no significant impact on ESC adoption, while a negative impact through a higher degree of contract's incompleteness was expected. This may come from the fact that in this context, the contract's duration is often determined by and equal to the technology's lifetime. Therefore, the negative impact predicted may be outweighed by the positive perception on long lasting technologies. The impact of trust, measured by the fact of having a backup of oil heating system (for mistrust of renewable technologies) and being in the same canton as the ESCO (for confidence towards the supplier), is significant and positive in the large sample.

[33] 236 offers in the regression sample provide this information.
[34] The characteristics are represented as the percentage of occurrence in non-mutually exclusive groups. Many projects combine several building types and clients. This is why the total is usually more than 100%.
[35] This number is larger than the 93% average of the residential variable (table 5) because the latter variable accounts for projects with only residential buildings.
[36] The descriptive statistics of the previous section are based on this larger sample.

Random Effects Probit dependent variable: offer accepted (y=1)	(1)		(2)	
oil backup	.		0.541***	
	.		(0.203)	
canton ESCO	0.005		0.550***	
	(0.191)		(0.127)	
ln(duration)	0.899		0.262	
	(0.640)		(0.198)	
technology specificity	0.003		0.009	
	(0.030)		(0.013)	
new building	0.850***		1.050***	
	(0.306)		(0.159)	
residential	0.970		0.997***	
	(0.593)		(0.214)	
intermediary	-0.639***		-0.553***	
	(0.166)		(0.086)	
rented	-1.251***		-1.224***	
	(0.429)		(0.197)	
interest rate	2.699***			
	(0.725)			
ln(TC/year)	-0.405**			
	(0.180)			
surface	0.000**			
	(0.000)			
observations	529.000		2003.000	
groups	321.000		1214.000	
year dummies	yes		yes	
	y=0	y=1	y=0	y=1
$\hat{y}$=0	407	76	1368	353
(%)	(97.84)	(67.26)	(94.80)	(63.04)
$\hat{y}$=1	9	37	75	207
(%)	(2.16)	(32.74)	(5.20)	(36.96)

Upper part of the table: Project-cluster robust standard errors in parentheses. *** P<0.01 ** P<0.05 * P<0.1. Oil backup omitted in (1) because predicts failure perfectly. Lower part of the table: See Appendix II for details on year dummies. y=0 (resp. y=1) indicate observed values of y vs $\hat{y}$=0 (resp. $\hat{y}$=1) indicate predicted values of y using estimated random effects and set to 1 if $P(y = 1|x) \geq 0.5$, 0 otherwise.

Table 8: Estimation results

This suggests that building a trustful relationship can appear to be important in order to reduce expected adaptation costs and can be seen as a substitute to contract's completeness.
The proxy for technology specificity, i.e. the inverse of the share of this technology in the Swiss real estate in that time period, does not show a significant impact on ESC adoption. One explanation

could be that, as predicted by the theory, what should matter in the client's choice is actually the interaction between specificity and contract's incompleteness[37]. The intuition that adoption is more likely in projects involving new buildings is confirmed here, supporting the importance of reduced physical and human asset specificity via more building flexibility. On the other hand, the proxy for the probability to find another client in case of disturbance, i.e. the dummy for residential building, shows the expected significant positive impact only in the larger sample.

Having more interlocutors taking part in the ESC contract, as it is the case when the client is an intermediary or when the building is rented, decreases as expected the probability to opt for ESC. It is quite interesting to add that the cause of the negative effect of rented housing lies in the risk of legal disputes with tenants and not in landlord-tenants split incentives. Indeed, a dummy variable that measures whether the owner lives or not in the building has no significant impact on ESC adoption once the fact of having a tenant is controlled for.

The perceived risk of legal disputes comes from the fact that the legal framework of transferring the costs of ESC onto the tenants in Switzerland remains unclear[38].

The nominal interest rate, measuring the project's risk borne and perceived by the ESCO shows a significant positive impact on ESC adoption. This means that the more risky is the project for the ESCO, the higher the probability for the client to sign the contract. This result is different from Polzin et al. (2016) who showed in the context of EPC adoption that collectivities tend to ignore the risk-sharing advantage of EPC. A positive impact of risk on the probability to externalize also contradicts the predictions of incentive-system theory. This result has nevertheless appeared quite often in the empirical literature on incentive system and agency theory[39]. One possible explanation is that the supplier is actually less risk averse than the client, making optimal for the latter to shed risk onto the ESCO[40]. The conjecture that the supplier is less risk averse than the client can be supported by the fact that the ESCOs may diversify the risks through their large portfolio of energy contracting projects and can benefit from higher technical knowledge than the client leading to better control and mitigation of technical risks. In this sample in particular, it is also supported by the fact that the two observed ESCOs are large Swiss utilities for whom energy contracting does not represent the company's main activity. This explanation is however puzzling in the context of the incentive system theory alone because it would mean that the trade-off between giving incentive and providing insurance to the agent fall apart. Indeed, considering only the basic determinants of the incentive system theory,

[37] See more discussion on this in the next section.

[38] In theory, when the energy equipment is external to the building, as for district heating for instance, the owner is allowed to transfer the costs of operation, maintenance, energy purchase and investment amortization into the renting charges. This represents therefore a clear advantage for owners because the rent (at least the fixed part) can be reduced correspondingly. Theoretically, the owner could do the same when the energy equipment is within the building but is owned by a third. This is the case in all ESC projects in this dataset when financed by the ESCO. In this case, the ESCO keeps the ownership of the installation until the end of the contract. To do that, it requires to the owner to sign an easement so that the room where the equipment is installed is owned by the ESCO. However, transferring the investment amortization within the charges in this case has never been subject to a legal precedent and no jurisprudence exist on this. Therefore, the risk of legal dispute remains high.

[39] see Lafontaine and Slade (2007) for a literature review.

[40] While Lafontaine and Slade (2007) argue that this explanation is not satisfactory in the context of franchisees and that the positive effect could come from an endogenous proxy for risk (variation in franchisees sales), I argue that the risk proxy used here is less likely to suffer from the same kind of endogeneity and that the assumption that the clients are more risk averse than ESCOs is plausible.

it would always be optimal for the client to choose ESC, which is not what is observed in reality. In order to have a trade-off underlying the ESC adoption choice, ESC's risk-sharing advantages must therefore be balanced with transaction cost economics determinants, such as expected adaptation costs or contract's incompleteness, or with other factors such as reduced competition as in McAfee and McMillan (1986). Another explanation for the positive effect of risk comes from the property-rights theory, as suggested by Lafontaine and Slade (2007). The latter predicts that the probability to externalize depends positively on the productivity of the agent's investments. One can argue that the more risky the project, the more important for the agent, i.e. the ESCO, to be flexible and reactive towards disturbances. For instance, when facing unpredicted technological issues, the ESCO develops higher technical skills to operate and maintain the installations. Therefore, in the presence of increased risk, the ESCO's investments become more productive, which in turns increases the probability for the client to choose ESC, as predicted by the property-rights theory.
Finally, while the client's size in terms of squared meters ($surface$) has a significant positive but small coefficient, the aggregate production costs, measured by $\ln(TC/year)$, have a signifcant negative impact on ESC adoption.

Table 9: Average Marginal Effects

	Effects on Pr(y=1)	
Variable	(1)	(2)
oil backup	.	0.160**
canton of the ESCO	0.001	0.135***
ln(duration)	0.199	0.070
technology specificity	0.001	0.002
new building	0.188***	0.226***
residential	0.214*	0.203***
rented	-0.276***	-0.382***
intermediary client	-0.141***	-0.153***
nominal interest rate	0.597***	
ln(TC/year)	-0.090**	
surface (m^2) by client	0.000**	
observations	529.000	2003.000
groups	321.000	1214.000

Average marginal effects (AME) are computed using estimated random effects (RE). P-values are estimated with random effects set to zero: *** P<0.01 ** P<0.05 * P<0.1. AME values are identical up to the fifth decimal if RE are set to zero or estimated. Oil backup omitted in (1) because predicts failure perfectly.

To capture the impact's magnitude of each determinants on ESC adoption, the average marginal effects are given in table 9. In terms of magnitude, the risk borne by the ESCO, proxied by the nominal interest rate, is clearly predominant with an increase close to 60 percentage points in the probability

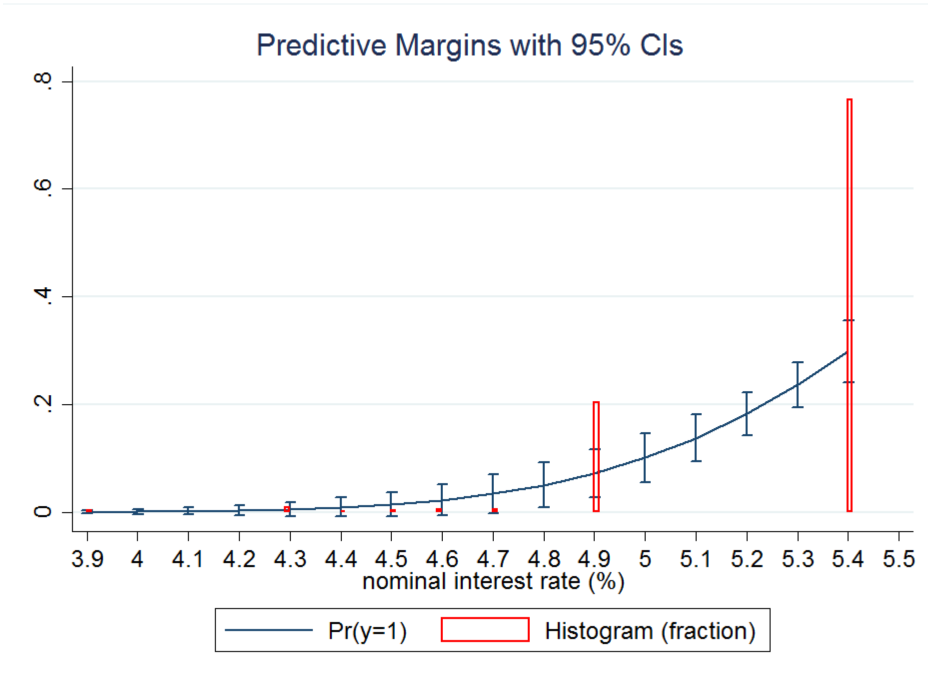

Figure 3

to sign the contract if the interest rate increases by 1 percentage point. Nevertheless, a 1 percentage point increase in the nominal interest rate is very large in this context since it corresponds to almost 4 standard deviations of this variable (see table 5). Figure 3 details the predicted probability to sign the contract for each level of nominal interest rate, together with the distribution of the latter variable in the sample. The probability to sign the contract, while all other covariates are set at their mean, is equal to 7.3% when the interest rate is set at 4.9% by the ESCO (corresponding to the projects with the second largest expected risk) and to 29.9% with an interest rate at 5.4% (for projects with the greatest expected risk).

The second factor in terms of magnitude relates to the fact of having tenants, with a negative impact from 28 to 38 percentage points on the probability to sign the contract. This suggests that the potential legal issues with respect to transferring the costs of ESC onto the tenants increase the expected adaptation costs and as such, constitute an important barrier to energy contracting.

The proxies for specificity, *residential* and *new_building*, follow in size with positive impacts of around 20 percentage points on ESC adoption. Then, if the client is an intermediary, adaptation costs are expected to increase, with a negative impact of around 15 percentage points on the probability to sign the contract. These estimated impacts provide some insights on the dilemmas aforementioned concerning residential but often rented buildings, and new building frequently involving intermediary clients. First, because the negative impact of rented buildings more than offsets the positive effect of residential buildings, ESCOs should not target residential buildings when they are known to involve

tenants[41]. Because of the unresolved legal issues aforementioned, they would indeed be better off targeting other types of buildings, such as industries or public buildings, rather than keeping on offering ESC contracts in rented residential buildings. It is the reverse that occurs in the case of new building involving intermediaries. Indeed, having increased expected adaptations via more actors involved such as intermediary clients is worth the cost since the positive impact of targeting new building is not offset by the negative effect of having more interlocutors[42].
Trust proxies show positive impacts on the probability to adopt ESC of 16 percentage points for oil backup corresponding to a perception of safer technology and 14 percentage points for canton of the ESCO, corresponding to a former relationship with the ESCO and presumably higher trust in the supplier. The latter effect is however not robust in the smaller sample of 529 observations and the impact of oil backup could not be tested in (1) due to perfect prediction of failure. It is however interesting to note that the impact of the variable *oilbackup* does not change through time[43], suggesting that the need for a technological insurance, such as an oil heating system working as a backup to more innovative technologies (such as heat pumps), is likely to be as important for clients in 2011 than it was in the 1990s. This in turns suggests that renewable and innovative energy heating systems may still be stereotyped as unsure, corresponding to a need for continuing information campaigns.

Finally, the negative impact of aggregate production costs ($\ln(TC/year)$) is explored in figure 4 using the predicted probabilities to sign the contract at several values of $TC/year$, together with the 95% confidence intervals, setting all other covariates at their mean value.

The squared term of $\ln(TC/year)$ did not show any significant impact and therefore, the predicted inverted-U impact on adoption is not observed. Clients with relatively small production costs for energy have a larger probability to opt for contracting than larger clients. This can suggest that the benefit due to economies of scale offset the transaction costs, even for the smallest clients. Figure 4 shows that the benefit of economies of scale decreases very rapidly. This result contradicting Sorrell's assumption must however be viewed cautiously since this dataset is characterized by an *ex ante* selection for relatively large clients. This can be seen in the detailed histogram in appendix III. Indeed, almost 85% of the offers are targeted to clients with yearly energy costs greater than 15,000CHF, corresponding already to buildings of 5-7 appartments. Thus, lacking a sufficient number of small clients in the dataset, this study may fail to capture the reduced suitability of ESC for small clients predicted by Sorrell (2007).

[41] For regression (2), a wald test on the average marginal effects of the variables *rented* and *residential* concludes in a rejection with 99% confidence level of the null hypothesis of the two average marginal effects being identical in absolute value: the impact of rented is significantly greater. The average marginal effect of *rented* was however not significantly greater in absolute value than the one from *residential* in the smaller sample (column (1)).

[42] For regression (2), a wald test on the average marginal effects of the variables *new* and *intermed* concludes in a rejection with 95% confidence level of the null hypothesis of the two average marginal effects being identical in absolute value: the impact of new is significantly greater. The average marginal effect of *new* was however not significantly greater in absolute value than the one from *intermed* in the smaller sample (column (1)).

[43] Using the larger sample of 2003 observations, this has been tested using a time trend interacted with the variable oil backup, which shown no significant impact.

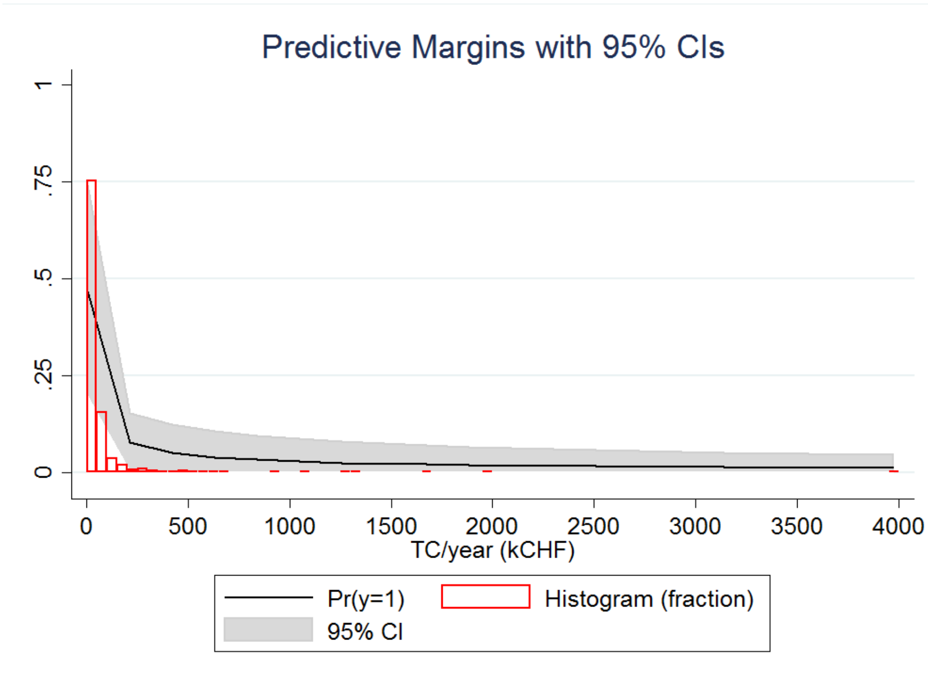

Figure 4

7. Robustness checks and limitations

The quality of the quadrature approximation of the random-effects model has first been checked and approved[44] for both regressions in table 2.
The robustness of the results have also been tested using a random-effects logit instead of probit, as can be seen in appendix IV. The average marginal effects are very similar, except from the average marginal effect of the residential variable which becomes unsignificant in the smaller sample.

A test was also performed to check whether the results concerning the aggregate energy costs and nominal interest rates are robust to changes in the number of observations. Indeed, the proxy for energy costs used suffers from a lot of missing values, coming from the fact that estimated hot water or heating consumption is missing when primary energy purchasing is not part of the contract (i.e. ESC in these kind of contracts looks like a leasing for the installation, including operation and maintenance of the equipment). Using estimation of hot water and heating consumptions with respect to building types and heated surface[45] increases the sample to 575 observerations. The results show that the impacts of $\ln(TC/year)$ and of the nominal interest rate on the probability to adopt ESC, found in

[44] This has been done by changing the number of integration points and explore how it affects the results. The relative differences between the coefficients when changing integration points from 8 to 16 (instead of 12 in table 2) were very small (of the order of $\cdot 10^{-6}$ to $\cdot 10^{-8}$), suggesting a quadrature approximation of quality.

[45] Hot water consumption was assumed to be 75MJ per squared meter heated surface (i.e. 75/3.6 kWh per m^2) in residential building and 50MJ in non-residential buildings. New buildings (respectively old buildings) were attributed a heating consumption of 100MJ/m^2 (respectively 250MJ/m^2)

the previous section, were robust to an increase in observations[46].

It was argued in the previous section that the counterintuitive positive effect of the risk borne by the ESCO on the contract's adoption may be explained by a need for the client, who may actually be more risk averse, to shed risk onto the supplier. Another explanation come from property rights theory. In order to explore the cause of this positive effect, one should test how the clients' and the ESCOs' risk aversion impact ESC adoption. It is however difficult to find plausible proxies for risk aversion. One available factor that has been tested was whether being a private vs. a public client had any impact —either directly or through the nominal interest rate impact— on adoption. The use of this determinant is supported by the fact that public entities are often considered in the economic literature as being risk neutral[47]. This variable had nevertheless no significant impact[48]. Then, while split incentives theory typically focuses on the risk borne by the agent (here the ESCO) it is interesting to explore whether the risk borne by the client, presumably more risk averse, is an important factor of ESC adoption. In ESC, the client typically bears the risk of energy prices or indices variations[49]. The impact of these variations has been tested in appendix V, using first the ratio of fixed cost on total cost which measures the part of the energy cost that is not subject to uncertainty, and then by using a measure of prices variability (namely the standard deviation)[50]. The price/index volatility measure shows a positive impact on adoption, suggesting that the higher the risk the client is facing, the more it is important for her to adopt ESC and share the rest of the risks with the ESCO. This result is however not robust in the larger sample, i.e. when omitting nominal interest rate, surface and aggregate energy costs.

The proxy for technology specificity does not show any significant result. One explanation could be that, as predicted by the theory, what should matter in the client's choice is the interaction between specificity and contract's incompleteness. Technology specificity is thus interacted with the determinants of contract's incompleteness (*oil backup*, *canton ESCO*, *duration*) and expected adapatation costs (*rented*, *intermediary client*), as shown in appendix VII. Only two interaction terms show significant effect, namely with the duration and the client being an intermediary. Appendix VII also shows graphically, together with the 95% confidence intervals, how the probability to adopt ESC evolve according to these factors. The results however contradict the theory since the specificity interacted with the elements of incompleteness show higher (and not lower) propensity to sign the contract. A further step to test the combined impact of specificity and contract's incompleteness would be to construct an interaction

[46]While the average marginal effect of $\ln(TC/year)$ does not change, the one of the nominal interest rate decreases to 53 percentage points (instead of 60 previously). As precendently, the squared term for $\ln(TC/year)$ gives no significant impact.

[47]see for instance McAfee and McMillan (1986)

[48]This may come from the fact that public clients represent a very small share in the sample, making it difficult to test it properly.

[49]When primary energy supply is included in the contract, as in a standard ESC contract, the variable cost determined into the contract is yearly indexed to the corresponding energy agent's index, as set by OFS (2014). There exist however some contracts called "light contracting", where the client keeps on buying the primary energy to her initial energy supplier. In this case, the variation in variable cost is determined by the variation in the market prices of the corresponding energy agents.

[50]price volatility is computed using 2000-2014 data on monthly energy prices (source OFS (2016)) for "light contracting" and of monthly energy indices (source OFS (2014)) for standard ESC contracts.

term, which would account for all the determinants of specificity on one hand, such as technology specificity, residential and new building dummies, and on the other hand all the factors influencing contract's incompleteness, i.e. trust and duration. This could be done in further research using factor analysis.
These counterintuitive results may also come from biases due to endogeneity inherent to specificity and contract's incompleteness factors. This empirical issue in testing transaction costs economics conjectures has been explained by Masten (1996) and tested by Saussier (2000). These authors consider that specificity as well as contract's incompleteness are endogenously chosen. As aforementioned, ex post adaptation costs could in fact be traded off with ex ante contractual design costs[51]. Similarly, one could think that the client chooses the level of technology specificity, given her choice to adopt ESC or not. There would be therefore a problem of reverse causality, which could be tested using an instrumental variable method as in Saussier (2000). One possible interesting instrument for technology specificity could be the proximity to energy sources, such as lakes or groundwater, which provide heating or cooling sources for innovative technologies such as heat pumps. This investigation is let for further research.

One should then consider the limitations of this research with regard to the lack of representativity of the data. Due to confidentiality and competition issues, only two ESCOs accepted to provide full information about their offers. This also has a consequence of possible selection bias. The dataset for instance contains a majority of private new residential buildings, heat pumps technologies and the offers are very often targeted towards relatively large clients. This selection may bias our results and further research would need to compare this dataset with data on offers made from other ESCOs and on clients who never received an ESC contract's offer. The latter could be done using a survey with stated preferences.

The dataset is also characterized by a larger number of refused than accepted offers. This, according to King and Zeng (2001), may lead to an underestimation of the predicted probability to sign the contract. This can also be seen at the bottom of table 8 where fitted values of y are better at predicting $y = 0$ than $y = 1$ in both regressions. Thus, average marginal effects for both regressions were again computed with balanced samples, using randomly chosen subsamples of the refused offers, with 113 rejected offers for regression (1) (respectively 561 for regression (2)). The average marginal effects results, after 400 random draws, are shown using histograms in appendix VI. The results show that the average marginal effects are often well distributed around the values initially found in table 9. A few variables show a more important impact in the larger sample (regression (2)), such as canton ESCO, new building, residential and intermediary client. This however does not seem to change the result of tenants offsetting the advantages of residential building and new buildings being interesting to target despite the often presence of intermediary clients[52]. One can also note that average marginal effects

[51] see Bajari and Tadelis (2001) for more on this.
[52] Indeed, the distribution of the average marginal effects (AME) of intermediary clients seem to lie between -0.15 and -0.25 and new buildings AME from 0.26 to 0.36. For rented buildings they lie between -0.31 and -0.41 while residential lie between 0.20 to 0.35.

computed this way are characterized by the presence of many outliers in the smaller sample (regression (1)), for residential and rented variables for instance. This is probably explained by the consequently reduced sample of 226 observations. Despite these observations, the general discussion lead at the previous section can be seen as robust while accounting for this problem of unbalanced sample.

Finally, limitations of the present results also rely in the estimation method. With the random effects method, it is assumed that there is no unobserved heterogeneity, i.e. the random effects are unrelated with the regressors. The latter assumption can be perceived as restrictive. However, the dataset does not provide flexibility in terms of estimation methods. Fixed effects or correlated random effects, suggested by Wooldridge (2009), did not prove to be suitable to the data since within variation of the variables of interest is not sufficient, i.e. the offers to each client do not change sufficiently from one another. Further research could consider other methods, such as latent class models, to account for potential unobserved heterogeneity or survival estimation methods (see Jenkins (2005)).

8. Conclusion

Using predictions from the theories on vertical integration, this study explores the barriers and drivers to energy supply contracting markets in Switzerland. Theoretical conjectures are tested using an original dataset of 2,003 rejected and accepted energy supply contracting offers of two ESCOs from 1996 to 2011. The analysis of the technologies proposed in these contracts suggest that ESC highly promotes energy renewable technologies. The estimation results show that some significant barriers hamper the development of the energy contracting market in Switzerland, supporting the possible existence of an *Energy Service Gap*.

The most binding constraint for the deployment of energy supply contracting (ESC) in Switzerland seems to be the perceived legal issues linked to rented buildings. This factor is closely related to the owner's expected adaptation costs related to the transfer of the contract costs onto the tenant. This result is likely to apply to energy performance contracting (EPC) as well, maybe in an even more important manner for two reasons. Firstly because EPC is exclusively targeting old buildings and increasing the rents when tenants are already living in the building is problematic. Second, the difficulty to transfer the costs of retrofit and energy efficiency measures may be more complex than in the case of energy service equipment owned by a third party as in ESC. A policy implication of this result is that there is a necessity to clarify this issue for both ESC and EPC. Interestingly, it has also been shown that the negative effect of having tenants seems rather to be due to the risk of legal disputes than caused by landlord-tenant split incentives. This would need to be explored as well in the context of EPC that involve energy savings, where split incentives are more likely to occur than in ESC.
The risk inherent to the project impacts positively the choice to externalize energy services, a priori contradicting incentive system theories. This result can nevertheless be interpreted as a need for the clients with risky projects to shed risk onto the ESCO who can diversify via a large portfolio of projects and other activities, as well as benefit from technical expertise and skills to mitigate technological risks. Another explanation coming from the property-rights theory can be that ESCOs bring higher

productivity in risky projects, due to their need to be reactive and flexible towards disturbances, which increases the interest for the client to adopt ESC in riskier projects.
The measures for trust in the technology and in the ESCO show an important impact on ESC adoption. This interestingly suggests that there still exists some reticence of customers towards renewable energy technologies, which can represent an important barrier to investment. The measure for trust towards the ESCO implies that having a preceding relationship with the supplier provides a significant advantage. These considerations on trust, either to the technology or the ESCO, is likely to play a role even more important in the EPC market, which is only emerging and where the concept is rather unknown on the demand-side. Economies of scale also appeared to be an interesting advantage of ESC, especially for small clients. This result should however be taken cautiously with regard to the insufficient share of small clients in the dataset.
Then, if the project is proposed to a new or a residential building, the probability to sign the contract increases. This can be explained by the fact that these projects are characterized by lower specificity and consequently lower sunk costs for the ESCOs in case of a disturbance, such as client's relocation or insolvency. This interpretation suggests that in order to target other types of clients, such as old or non-residential buildings, ESCOs would need some safety nets regarding the risk of client's relocation or bankruptcy. Klinke et al. (2015) provide and develop advantages and shortcomings of some potential answers to mitigate those risks, such as the use of contractual clauses, real estate liens, guarantee funds created by ESCOs' associations, pooling projects in a "Super ESCO" or public institutions support.
This study also shows that the ESCOs must properly account for the trade-offs underlying the type of clients they are targeting. Residential and new buildings present the advantage of less specific investments and more flexibility in the technological installation. Yet, these advantages must be balanced with the tenants and intermediary clients they often involve. While new buildings' advantage offset the expected adaptation costs linked with intermediary clients, this is not the case for residential buildings involving tenants. Therefore, as long as the legal risk with tenants is not resolved, ESCOs would be better off targeting non-residential (and not rented) buildings.
Finally, the technology specificity did not show the impact predicted by the economic theory. Further research would be needed to assess whether a better proxy can be found and if other estimation methods would correct for potential endogeneity biases. If even so, physical asset specificity does not significantly affect ESC adoption, this would represent a good news for policymakers. Indeed, while ESC and EPC have been seen as promising instruments to promote and induce investment, some authors have argued that, as predicted by the transaction cost economics, they are targeting low hanging fruits, i.e. only generic technologies which reduce uncertainty, at the expense of more comprehensive energy service projects with higher energy efficiency opportunities (Mills (2003),Sorrell (2007)). If technology specificity can be proven to have no impact on the customer's choice, then this suggests that it would be nonstrategic for the ESCOs to propose generic technologies and this should therefore no longer be considered as a shortcoming of energy service contracting.

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10. Appendix

Appendix I: A simple model of ESC adoption rooted in transaction costs economics

The model described here uses a simplified version of the formal model developed by Tadelis and Williamson (2013). The main difference here is that the energy customer optimizes only over an incentive scheme given to the supplier. In their model, the buyer optimizes over both the incentive scheme and the mode of governance. I argue that in the context of energy service contracting, the incentive scheme alone is sufficient to distinguish between the different types of energy service provision and allows to fully capture the trade-offs underlying energy service contracting adoption.

10.1. Production costs

Production costs are given by:

$$C(e) = \bar{c} - e \tag{5}$$

and represent the total costs for all the activities necessary to provide useful energy, i.e. $C(e) = C = \sum_j c_j$ in Table 1. $0 \leq e < \bar{c}$ represents the endogenously chosen amount of supplier's effort put into the project, which depends on z. The supplier's opportunity cost of effort is $y(e)$, assuming $y'(e) > 0$, $y'(0) = 0$, $y''(e) > 0$, $y'''(e) = 0$. As in Tadelis and Williamson (2013) and in agency theory, it is further assumed that it is not possible to contract directly on unobservable effort.

10.2. Adaptation costs

Adaptation costs

$$K(z) > 0 \tag{6}$$

are incurred *ex post* in case an exogenous disturbance occurs and that adaptations are needed in order to obtain the same utility value v from the energy service[53]. Depending on the kind of disturbances, adaptation costs can in practice be borne either by the ESCO or the client. However, assuming perfect competition *ex ante*, i.e. at the time of the tendering process, any ESCO's expected adaptation cost will be incorporated into its bid and will consequently be transferred to the client (Bajari and Tadelis (2001), Bajari et al. (2014)).

I assume $K'(z) > 0$, i.e. the higher the supplier's cost share the higher the adaptation costs. Furthermore, $K''(z) \geq 0$ is assumed so that the gain from adaptation when a higher share is borne by the supplier is evolving at a non-decreasing rate.

Since adaptation costs are incurred *ex post*, at the time the customer must choose whether to adopt ESC, it is the expected value of the adaptation costs that matters. And a disturbance is not sufficient in itself to incur adaptation costs. Adaptation costs are expected to occur with a probability $\rho\sigma$, i.e.

[53] As opposed to incentive-system theories or Property-rights theory, which focus on *ex ante* optimal incentive to invest in specific assets, in transaction cost economics the main determinant of decisions concerning the organizational forms of transactions are determined by *ex post* adaptation

only if the interaction of two components take place[54]. First, contract's incompleteness will appear in $\rho \in [0,1]$ which corresponds to the probability that the contract will be renegotiated due to a disturbance. Second, asset specificity will be represented by $\sigma \in [0,1]$, which is the probability that the supplier (or the buyer) cannot be replaced by a competitor when disturbance occurs.

10.3. Optimization and results

The supplier's profit maximization and the first order condition are given by:

$$\begin{aligned} &\max_{e} \pi(e,z) = F - z \cdot (\bar{c} - e) - y(e) \\ &FOC\ : y'(e) = z \end{aligned} \tag{7}$$

The first order condition implies, following $y''(e) > 0$, that $\frac{\partial e}{\partial z} > 0$. Thus, a relatively higher supplier's cost share provides him with an incentive to increase effort and hence, reduces production costs.
The customer's optimization is presented by:

$$\begin{aligned} &\max_{z} U(e,z) = v - \sigma\rho K(z) - F - (1-z) \cdot [\bar{c} - e] \\ &\text{s.t. } e = y'^{-1}(z) \end{aligned} \tag{8}$$

where $v - \sigma\rho K(z)$ is the expected gross benefit from the transaction and is positive because it is assumed $v - K(z) > 0$. That is, the energy service's value is worth risking *ex post* adaptation costs. The customer optimizes expected gross benefit minus payment, given the supplier's optimal amount of effort provided, which is represented in the incentive compatibility constraint.

The customer's first order condition is:

$$FOC\ : F(z,\sigma,\rho) = \bar{c} - [y'^{-1}(z)] + (1-z)[(y'^{-1})'(z)] - \sigma\rho K'(z) = 0 \tag{9}$$

Using the implicit function theorem, I find:

$$\frac{\partial z}{\partial \sigma} = -\frac{\frac{\partial F(z,\sigma,\rho)}{\partial \sigma}}{\frac{\partial F(z,\sigma,\rho)}{\partial z}} = -\frac{-\rho K'(z)}{-2\left[(y'^{-1})'(z)\right] + (1-z)\left[(y'^{-1})''(z)\right] - \sigma\rho K''(z)} \tag{10}$$

It is then possible to show that:

$$(y'^{-1})'(z) = \frac{1}{y''(y'^{-1}(z))} > 0 \tag{11}$$

Because $y'^{-1}(z) = e \geq 0$ and I assumed $y''(e) > 0$. Furthermore:

$$(y'^{-1})''(z) = \frac{-y'''\left(\left(y'^{-1}(z)\right)\right) \cdot (y'^{-1})'(z)}{\left(y''(y'^{-1}(z))\right)^2} = 0 \tag{12}$$

[54]As a result, expected adaptation costs are given by $\rho\sigma K(z)$

Since, $y'''(e) = 0$. And because I assumed $K'(z) > 0$ and $K''(z) \geq 0$, I find:

$$\frac{\partial z}{\partial \sigma} = \frac{\rho K'(z)}{-2\left[(y'^{-1})'(z)\right] - \sigma\rho K''(z)} < 0 \tag{13}$$

Thus, σ (similarly ρ) has a negative impact on the solution of the customer's optimization, and thus on the customer's optimal choice z^*:

$$z^* = \begin{cases} 0 \text{ if } \operatorname{argmax}\{U(z)\} \leq 0 \\ \operatorname{argmax}\{U(z)\} \text{ if } 0 < \operatorname{argmax}\{U(z)\} < 1 \\ 1 \text{ otherwise} \end{cases}$$

Finally, the clients signs the ESC contract if and only if $z^* \geq z_{ESC}$. As a result, asset specificity σ and contract's incompleteness ρ have a negative impact on the probability to opt for ESC.
Furthermore, $K'(z)$, which can be related to the magnitude of expected adaptation costs, also positively affects the impacts of σ (respectively ρ) on ESC adoption.

Appendix II: Year dummies detail

Random Effects Probit dependent variable: offer accepted (y=1)	(1)
oil backup	0.541***
	(0.203)
canton of the ESCO	0.550***
	(0.127)
ln(duration)	0.262
	(0.198)
specificity	0.009
	(0.013)
new building	1.050***
	(0.159)
residential	0.997***
	(0.214)
intermediary client	-0.553***
	(0.086)
rented	-1.224***
	(0.197)
year==1998	0.975
	(0.752)
year==1999	0.606
	(0.662)
year==2000	0.270
	(0.619)
year==2001	1.810***
	(0.676)
year==2002	-0.811
	(0.791)
year==2003	-0.323
	(0.634)
year==2004	0.119
	(0.627)
year==2005	0.105
	(0.602)
year==2006	-0.178
	(0.603)
year==2007	0.395
	(0.605)
year==2008	0.564
	(0.615)
year==2009	0.524
	(0.605)
year==2010	0.762
	(0.610)
year==2011	0.588
	(0.625)
Observations	2003.000
Groups	1214.000

Project-cluster robust standard errors in parentheses.
*** P<0.01 ** P<0.05 * P<0.1.
Base: years 1996 and 1997 (1996 predicts failure perfectly)

Appendix III: TC/year histogram detailed

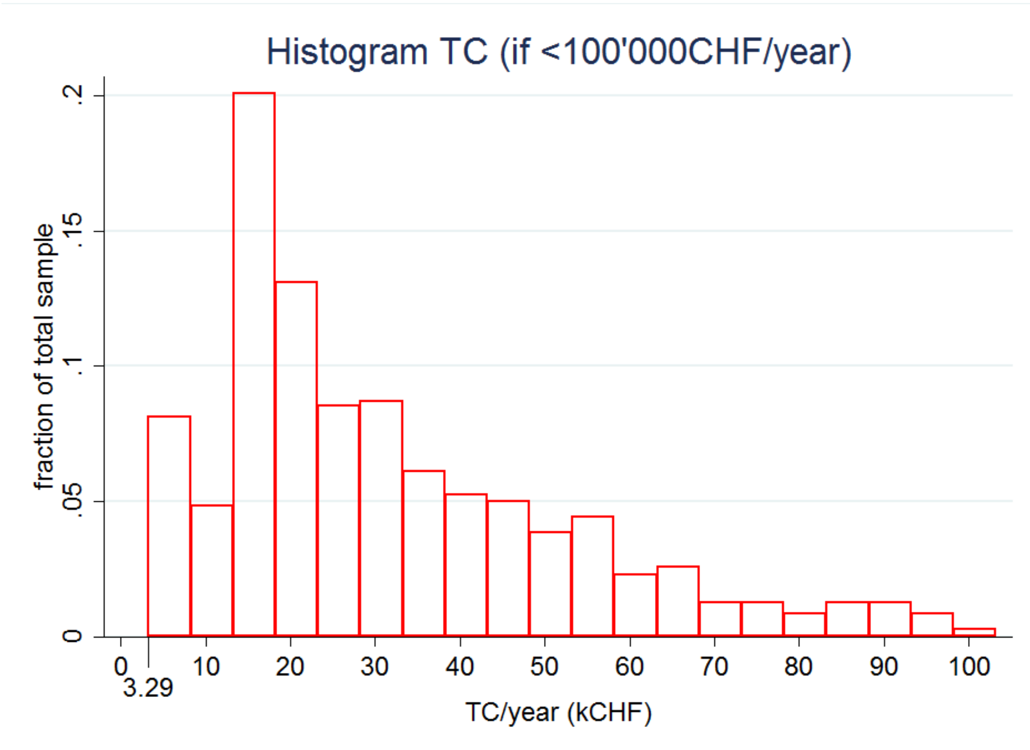


Figure 5

Appendix IV: Logit RE

Table 10: Random effects logit results

Random Effects Logit dependent variable: offer accepted (y=1)	(1)	(2)
oil backup	.	0.992***
	.	(0.358)
canton of the ESCO	-0.024	0.930***
	(0.343)	(0.226)
ln(duration)	1.760	0.469
	(1.424)	(0.348)
specificity	0.010	0.018
	(0.063)	(0.023)
new building	1.666**	1.889***
	(0.665)	(0.299)
residential	1.669	1.820***
	(1.158)	(0.390)
rented	-2.217***	-2.155***
	(0.692)	(0.346)
intermediary client	-1.083***	-0.938***
	(0.296)	(0.149)
nominal interest rate	4.887***	
	(1.394)	
ln(TC/year)	-0.691**	
	(0.346)	
surface (m^2) by client	0.000**	
	(0.000)	
observations	529.000	2003.000
groups	321.000	1214.000
year dummies	yes	yes

	y=0	y=1	y=0	y=1
$\hat{y}$=0	407	76	1368	353
(%)	(97.84)	(67.26)	(94.80)	(63.04)
$\hat{y}$=1	9	37	75	207
(%)	(2.16)	(32.74)	(5.20)	(36.96)

Upper part of the table: Project-cluster robust standard errors in parentheses. *** P<0.01 ** P<0.05 * P<0.1. Oil backup omitted in (1) because predicts failure perfectly. Lower part of the table: y=0 (resp. y=1) indicate observed values of y vs $\hat{y}$=0 (resp. $\hat{y}$=1) indicate predicted values of y using estimated random effects and set to 1 if $P(y = 1|x) \geq 0.5$, 0 otherwise.

Table 11: Average Marginal Effects (Logit RE)

	Effects on Pr(y=1)	
Variable	(1)	(2)
oil backup	.	0.171***
canton of the ESCO	-0.003	0.130***
ln(duration)	0.221	0.072
specificity	0.001	0.003
new building	0.209**	0.227***
residential	0.209	0.205***
rented	-0.278***	-0.396***
intermediary client	-0.136***	-0.150***
nominal interest rate	0.612***	
ln(TC/year)	-0.087**	
surface (m^2) by client	0.000**	
observations	529.000	2003.000
groups	321.000	1214.000

Average marginal effects (AME) are computed using estimated random effects (RE). P-values are estimated with random effects set to zero: *** P<0.01 ** P<0.05 * P<0.1. AME values are identical up to the fourth decimal if RE are set to zero or estimated.

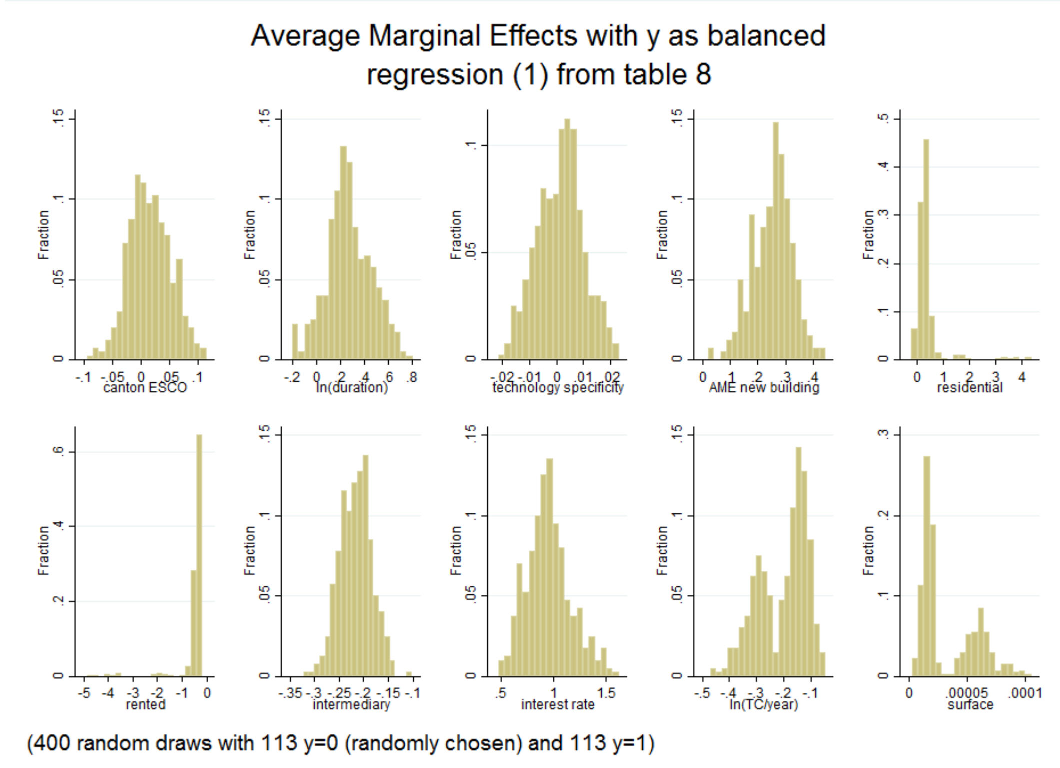
Appendix V: Client's risk

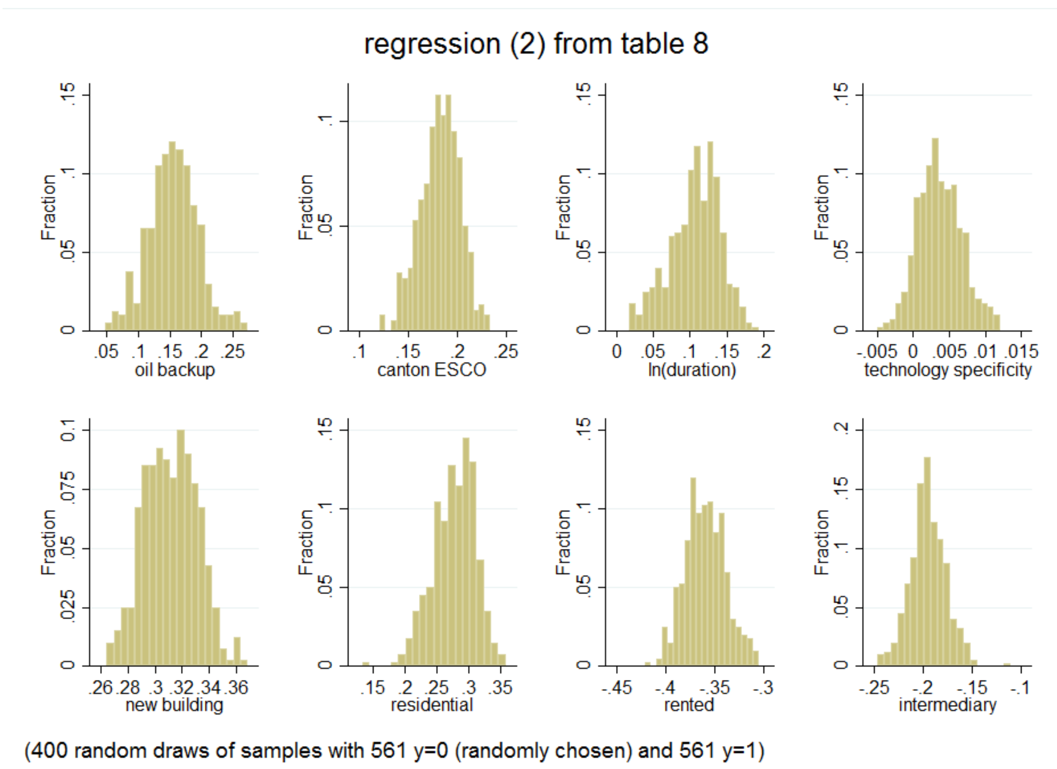
Random Effects Probit dependent variable: offer accepted (y=1)	(1)	(2)	from (1),(2)	Average Marginal Effects (3)	
fixed cost/total cost	-0.000			-0.000	
	(0.000)				
client's risk		0.094**		0.021**	0.001
(std dev of monthly		(0.046)			(0.015)
energy indices/prices)					
nominal interest rate	2.716***	2.965***	2.959***		
	(0.690)	(0.678)	(0.676)		
oil backup	.	.	.		0.539*
	.	.	.		(0.300)
canton of the ESCO	0.017	0.031	0.033		0.546***
	(0.193)	(0.192)	(0.192)		(0.126)
ln(duration)	0.922	1.198*	1.297*		0.260
	(0.631)	(0.645)	(0.672)		(0.198)
specificity	0.010	0.000	-0.002		0.008
	(0.031)	(0.028)	(0.029)		(0.013)
new building	0.769**	0.920***	0.922***		1.060***
	(0.307)	(0.324)	(0.323)		(0.158)
residential	1.250*	1.195*	1.190*		1.012***
	(0.725)	(0.696)	(0.688)		(0.206)
intermediary client	-0.630***	-0.689***	-0.685***		-0.554***
	(0.168)	(0.164)	(0.164)		(0.086)
rented	-1.342***	-1.469***	-1.452***		-1.221***
	(0.435)	(0.433)	(0.430)		(0.190)
ln(TC/year)	-0.285	-0.560***	-0.548***		
	(0.281)	(0.197)	(0.196)		
surface (m^2) by client	0.000*	0.000**	0.000**		
	(0.000)	(0.000)	(0.000)		
observations	529.000	529.000	529.000		1999.000
groups	321.000	321.000	321.000		1210.000
year dummies	yes	yes	yes		yes

Upper part of the table: risk is computed using volatility from 2000-2014 of monthly energy prices (source OFS (2016)) for ESC contracts without primary energy supply included (light contracting) and of monthly energy indices (source OFS (2014)) for standard ESC contracts. Project-cluster robust standard errors in parentheses. *** P<0.01 ** P<0.05 * P<0.1. Oil backup omitted because predicts failure perfectly.

Table 12: Results on client's risk

Appendix VI: Average marginal effects with y as balanced





Appendix VII: Specificity interactions

Random Effects Probit dependent variable: offer accepted (y=1)	(1)	(2)	(3)	(4)	(6)
specificity	0.007	0.010	-0.188**	-0.016	-0.009
	(0.014)	(0.028)	(0.091)	(0.021)	(0.014)
specificity · oil backup	0.209				
	(0.555)				
specificity · canton ESCO		-0.001			
		(0.031)			
specificity · ln(duration)			0.065**		
			(0.029)		
specificity · rented				0.036	
				(0.025)	
specificity · intermediary client					0.050**
					(0.022)
oil backup	-20.237	0.541***	0.414**	0.526***	0.534***
	(55.316)	(0.203)	(0.201)	(0.195)	(0.205)
canton of the ESCO	0.548***	0.659	0.549***	0.548***	0.560***
	(0.127)	(2.909)	(0.127)	(0.127)	(0.128)
ln(duration)	0.260	0.262	-5.791**	0.263	0.272
	(0.197)	(0.198)	(2.658)	(0.197)	(0.196)
rented	-1.223***	-1.224***	-1.251***	-4.623**	-1.235***
	(0.196)	(0.197)	(0.193)	(2.359)	(0.193)
intermediary client	-0.554***	-0.554***	-0.557***	-0.554***	-5.180**
	(0.086)	(0.086)	(0.086)	(0.086)	(2.062)
new building	1.047***	1.051***	1.066***	1.042***	1.029***
	(0.159)	(0.161)	(0.156)	(0.156)	(0.156)
residential	0.986***	0.997***	1.036***	0.975***	0.999***
	(0.217)	(0.214)	(0.210)	(0.213)	(0.210)
observations	2003.000	2003.000	2003.000	2003.000	2003.000
groups	1214.000	1214.000	1214.000	1214.000	1214.000
year dummies	yes	yes	yes	yes	yes

Upper part of the table: Project-cluster robust standard errors in parentheses. *** P<0.01 ** P<0.05 * P<0.1.

Table 13: Results on specificity interactions

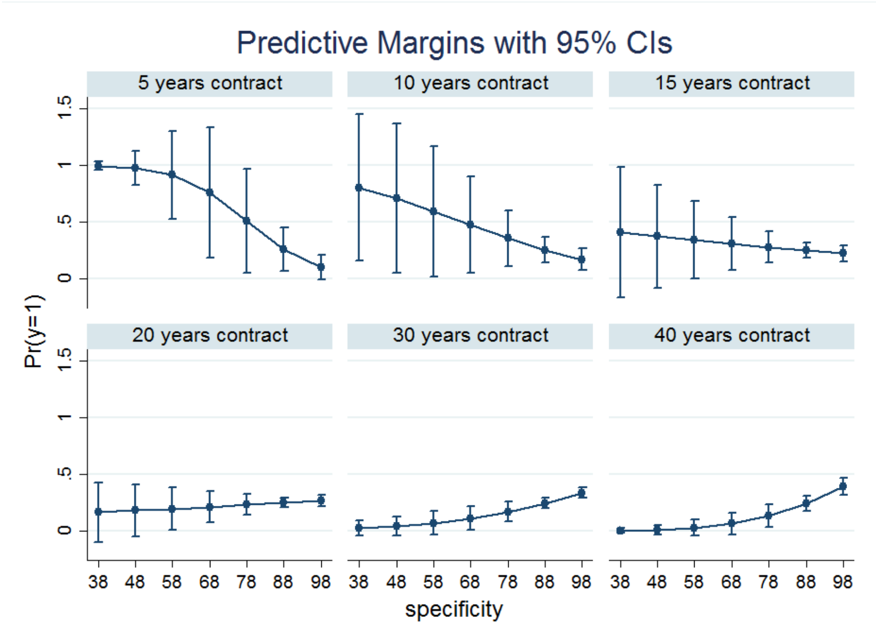


Figure 6: specificity · duration

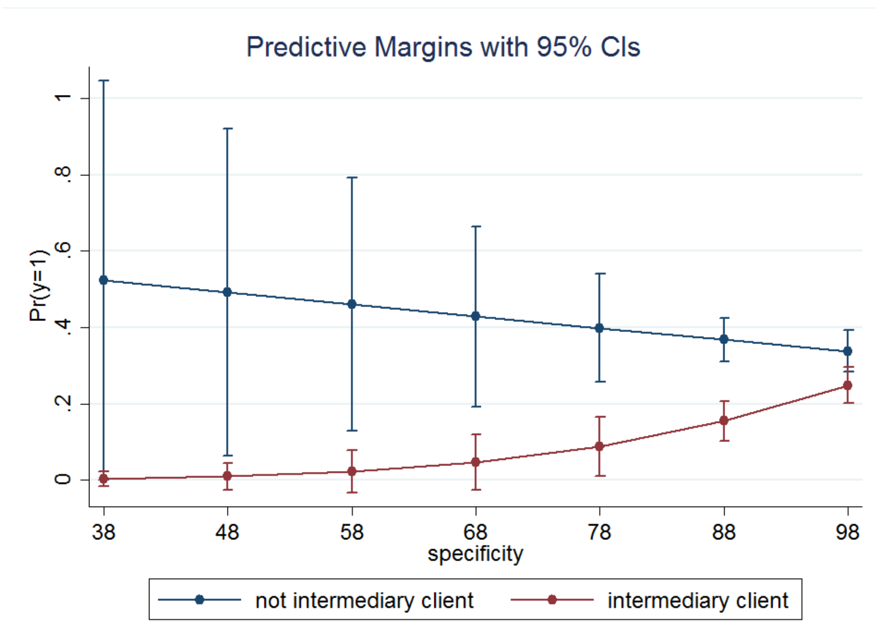


Figure 7: specificity · intermediary client