FINAL REPORT

Analysis of the production efficiency of the Swiss forestry firms with regard to the forest functions

Commissioned by the Federal Office for the Environment (FOEN)

April 2013

Imprint

Commissioned by: Federal Office for the Environment (FOEN), Forest Division, CH-3003 Bern
The FOEN is an agency of the Federal Department of the Environment, Transport, Energy and Communications (DETEC).
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Note: This study was prepared under contract to the Federal Office for the Environment (FOEN). The contractor bears sole responsibility for the content.

Content

Tables and Figures

Zusammenfassung

Schweizer Forstbetriebe weisen über die letzten zwei Jahrzehnte in der Waldbewirtschaftung wachsende Unterdeckungen auf. Diese Entwicklung ist beunruhigend, ist doch bei einer nachhaltigen Waldbewirtschaftung auch die ökonomische Komponente zu berücksichtigen. Massnahmen sind notwendig, um die Produktionseffizienz zu verbessern und die Kosten weiter zu senken, dies bei gleichzeitiger Aufrechterhaltung der Leistungen zu Gunsten der gesellschaftlichen Wohlfahrt, die von diesen Betrieben erbracht werden. Die Literatur bezüglich der Leistungsfähigkeit der schweizerischen Forstbetriebe, welche auf statistische und ökonometrische Methoden zurückgreift, ist begrenzt. Eine gewisse Anzahl an Referenzen beruht auf Fallstudien, welche Massnahmen empfehlen, die zum Ziel haben, die Effizienz bei der Holzproduktion zu steigern. Die seltenen ökonometrischen Studien über die produktive Leistung der Forstbetriebe basieren auf einem einzigen Output – der Holzproduktion – ohne die multifunktionelle Rolle des Waldes zu berücksichtigen.

Eines der wichtigen Ziele der vorliegenden Studie, die vom BAFU in Auftrag gegeben worden ist, ist es, die wirtschaftliche und technische Leistungsfähigkeit der schweizerischen Forstbetriebe zu untersuchen, bei gleichzeitiger Berücksichtigung der multifunktionellen Rolle des Waldes. Dies ist heute aufgrund der Verfügbarkeit von analytischen Abrechnungsdaten, welche seit 2004 für die 200 Betriebe, die im forstwirtschaftlichen Testbetriebsnetz der Schweiz (TBN) zusammengefasst sind, möglich. Die Finanz- und Produktionsdaten berücksichtigen unter anderem die Holzproduktion (2. Produktionsstufe) der Forstbetriebe, welche im Rahmen der vier Waldfunktionen (Holzproduktion, Schutz vor Naturgefahren, Freizeit & Erholung, Biodiversität) durchgeführt werden.

Die Forstbetriebe treffen, per Definition, selbständig Entscheidungen über das Produktionsniveau und den Einsatz der Faktoren (Inputs). Die technische Effizienz eines Betriebes kann über die relative Differenz, die zwischen den beobachteten Werten des Niveaus der Outputs und Inputs und dem geschätzten Wert, welcher der Produktionsgrenze entspricht, besteht, geschätzt werden. Eine andere Möglichkeit, die Leistungsfähigkeit zu analysieren, besteht darin, eine Kostenfunktion für die Produktion ökonometrisch zu schätzen. Der Einsatz von Kostenfunktionen ermöglicht es sowohl die Grenzproduktionskosten und den Einfluss der unterschiedlichen Kostendeterminanten als auch das Bestehen von Skalenerträgen und einer optimalen Grösse eines Forstbetriebes zu bestimmen.

Die wichtigsten Forschungsfragen wurden vorab mit dem BAFU definiert. Die gesetzten Ziele beinhalten unter anderem die Schätzung des Niveaus der technischen Effizienz der Forstbetriebe und die Identifizierung der verschiedenen Einflussfaktoren, wie zum Beispiel die öffentlichen Finanzbeiträge, der Eigentumstyp oder das Ausmass der Diversifizierung der Produktion und Dienstleistungen. Die Studie trägt ebenfalls zur Beurteilung der Qualität der Daten für zukünftige Forschungsarbeiten, insbesondere hinsichtlich der unterschiedlichen Waldfunktionen, bei.

Die Ergebnisse, die mit Hilfe der unterschiedlichen ausgewählten empirischen Ansätze erzielt wurden, stimmen weitgehend überein. Die Ergebnisse bezüglich der **technischen Effizienz** deuten an, dass das Durchschnittsniveau bei der Holzproduktion, wie auch bei den anderen Waldfunktionen, relativ niedrig ist. Dies würde bedeuten, dass Inputs wie Beschäftigung,

Maschinen oder sogar die Ausgliederung von Leistungen an Dritte signifikant gesenkt werden könnten, ohne dass die Mehrheit der Betriebe ihre Produktion reduzieren müsste. Erklärt werden könnte dies durch die hohe unbeobachtete Heterogenität der Betriebe als auch durch aussermarktliche Zwänge, die diesen Betrieben auferlegt werden. Ein „Benchmarking" – der Vergleich zwischen Betrieben – hinsichtlich der beobachteten Eigenschaften der Betriebe zeigt zum Beispiel auf, dass die effizienten Betriebe sich weniger um Schutzwald kümmern müssen oder sich in der Region Mittelland befinden. Die Ergebnisse zeigen zudem auf, dass die wenig diversifizierten Betriebe (Fokussierung auf Holzproduktion), effizienter sind als die diversifizierten Betriebe. In der Tat erreichen während der Beobachtungsperiode die Forstbetriebe, deren Holzverkauf mehr als 80% der Gesamteinnahmen ausmacht, einen im Durchschnitt signifikant höheren Effizienzwert als die Betriebe, deren Holzerlöse weniger als die Hälfte der Einnahmen ausmachen. Generell zeigt sich die geographische Lage (Region, Topographie) als ein sehr einflussreicher Faktor für das Verhalten und die technische Effizienz der Betriebe.

Im Durchschnitt nutzen die TBN-Betriebe die bestehenden **Skaleneffekte**. Die Data Envelopment Analysis (DEA) zur Holzproduktion über sämtliche Waldfunktionen zeigt, dass fast drei Viertel der TBN-Forstbetriebe ein Produktionsniveau erreicht haben, welches von abnehmenden Skalenerträgen (hinsichtlich der Holzproduktion) charakterisiert ist. Anders gesagt liegt im Durchschnitt das Produktionsniveau bei der Mehrheit der Betriebe oberhalb des Niveaus bei welchem die Durchschnittskosten am niedrigsten wären – d.h. dem sogenannten im Rahmen dieser Studie ermittelten technisch „optimalen" Produktionsniveau. Die „optimale" Produktion eines typischen Betriebs wäre demnach bei etwa 5'000 m3 oder, in Waldfläche ausgedrückt, bei etwa 1'000 ha. Betrachtet man die einzelnen Waldfunktionen liegt diese „optimale" Grösse tiefer. Beispielsweise liegt das „optimale" Produktionsniveau für den Naturwald (Biodiversität) bei weniger als 1'000 m3. Die Produktionsschwelle ist jedoch von einer Region zur anderen unterschiedlich. Dennoch gibt es immer noch eine recht grosse Minderheit von kleineren Betrieben, die von einer Vergrösserung des Betriebs, durch Zusammenarbeit oder Fusion, profitieren könnten. Die bestehenden Anreize sind anscheinend nicht ausreichend, um die Transaktionskosten und die individuellen strategischen Überlegungen der öffentlichen Waldeigentümer zu überwinden.

Auf rein theoretischer Ebene können die **finanziellen Beiträge** des Staates zu Ineffizienz beitragen, da sie ebenfalls den Marktdruck verringern. Über die Richtung der Kausalität ist es schwierig definitive Aussagen zu machen. Der nichtparametrische Ansatz zeigt, dass die effizienten Betriebe dazu neigen, weniger finanzielle Unterstützung zu erhalten (in Prozent der Einnahmen). Andererseits üben die finanziellen Beiträge, im Falle der alleinigen Holzproduktionsfunktion, einen positiven Effekt auf die produktive Effizienz aus. Es ist auch nicht ausgeschlossen, dass bestimmte Beiträge zum Schutzwald und zur Unterstützung der Leistungen zu Gunsten der gesellschaftlichen Wohlfahrt indirekt die Effizienz der Holzproduktion steigern. Auf der Kostenebene zeigen die empirischen Schätzungen, dass die finanziellen Beiträge einen recht bedeutenden Einfluss auf die Kosten haben, indem sie das Verhalten der Betriebe bei ihren Entscheidungen beeinflussen. Dieses Ergebnis impliziert jedoch keine generellen waldpolitischen Schlussfolgerungen. Es ist nämlich gut möglich, dass die Betriebe, deren Produktion relativ kostengünstig ist, weniger öffentliche Beiträge erhalten, weil sie sie schlicht und einfach nicht benötigen. Leider erlauben es die zur Verfügung stehenden Daten nicht, die Kausalitäten in jedem Fall zu identifizieren.

Was die Effizienz der **Produktion nach Waldfunktion** angeht, so scheint es, dass die Holzproduktion in den Schutzwäldern am wenigsten effizient ist. Dies lässt sich damit erklären, dass die Holzproduktion in den Schutzwäldern im Wesentlichen gar nicht das Hauptziel darstellt. Schutzwälder finden sich meistens in den Regionen „Voralpen" und Alpen, wo der Holzzuwachs klimatisch bedingt tief ist, das Produktionsvolumen niedriger ist und die Inputs aufgrund der aufwändigen Holzerntebedingungen verhältnismässig hoch sind. Dennoch deuten die Ergebnisse darauf hin, dass gewisse Synergien zwischen der Holzproduktion und den anderen Leistungen zu Gunsten der öffentlichen Wohlfahrt existieren, da die empirischen Schätzungen auf eine Komplementarität der jeweiligen Kosten hindeuten. Zusätzlich zum Ausnützen von Skaleneffekten stellt die Kosten-Komplementarität der Funktionen einen weiteren Grund dar, die Fusion von Betrieben und forstwirtschaftlichem Eigentum, oder zumindest eine engere Zusammenarbeit, voranzutreiben. Andererseits wird eine **Externalisierung** der Produktion zur Kostenreduzierung oder um ein besseres Ressourcenmanagement zu gewährleisten immer häufiger benutzt. Es zeigt sich klar, dass die Externalisierung positive Auswirkungen auf die Kosteneffizienz hat.

Es gibt zurzeit auf Bundesebene nur eine begrenzte Zahl von Massnahmen, die darauf abzielen, die Effizienz der Produktion zu verbessern oder die Produktionskosten zu senken. Diese Programme unterstützen die forstliche Zusammenarbeit mit Hilfe einer Kostenbeteiligung bei der Umsetzung und versuchen die Effizienz im Bereich Logistik und Planung unter Berücksichtigung einer nachhaltigen Bewirtschaftung des Waldes, unter anderem durch Beiträge zur Betreuung von Jungwäldern, zu fördern. In Anbetracht der drohenden Defizite wurden auch einige spezifische Massnahmen getroffen, um die öffentlichen Waldbesitzer und die grösseren Betriebe dazu zu bringen, ihre wirtschaftliche Leistungsfähigkeit bei der Holzproduktion und bei den anderen Waldfunktionen zu verbessern (Good Practice Workshops, Benchmarking-Zirkel, Information, Aus- und Weiterbildung).

Der Schweizer Wald wächst und breitet sich weiter aus. Das nachhaltige Holznutzungspotential wird aktuell nicht ausgeschöpft, die Holznutzung kann deutlich erhöht werden, ohne dabei die natürlichen Ressourcen des Waldes zu beinträchtigen. Eine Erhöhung der Produktion innerhalb des vorgegebenen Rahmens auf dem heimischen (oder internationalen) Markt kann zu einer Verbesserung der Produktion führen. Es gibt jedoch heute zahlreiche Zwänge und Hindernisse, die überwunden werden müssen, wie zum Beispiel die noch begrenzte Nachfrage für Schweizer Holz, suboptimale Prozesse und Strukturen in der Wertschöpfungskette, hohe Transportkosten und seit kürzerem der teure Schweizer Franken, der Importe begünstigt und Exporte erschwert. Ebenso dürfen die nicht wirtschaftlichen Funktionen und deren Wechselwirkungen mit der Holzproduktion nicht ignoriert werden. Es scheint, dass mehr Forschung über das Angebot und die Nachfrage auf den Holzmärkten notwendig ist, um die Mechanismen zu identifizieren, die die Effizienz verbessern können.

Wir danken der Sektion „Wald- und Holzwirtschaft" des Bundesamts für Umwelt (BAFU), uns die Möglichkeit gegeben zu haben, an diesem Thema arbeiten zu dürfen. Ein besonderes Dankeschön geht an den Sektionschef Alfred Kammerhofer und seinen Stellvertreter Matthias Kläy für ihre Kommentare und relevanten Beobachtungen während der gesamten Dauer des Projekts. Wir möchten ebenso gegenüber den Datenlieferanten, dem Bundesamt für Statistik und der Waldwirtschaft Schweiz, für ihre Unterstützung unseren Dank aussprechen. Wir bedanken uns ebenfalls bei den Teilnehmern des Workshops vom 7. November 2012, welcher vom BAFU organisiert wurde, insbesondere Roland Burri, Christoph Hartebrodt, Bernard Pauli, Oliver Thees und Willi Zimmermann, für ihre nützlichen Kommentare.

Die Autoren gehen aktuell ihren Recherchen im Bereich Waldwirtschaft im Rahmen des Projekts „Den Holzmarkt verstehen: zwischen Versorgung und Multifunktionalität", welches durch das Nationale Forschungsprogramm NFP 66 „Ressource Holz" während der Jahre 2013 bis 2015 finanziert wird, weiter nach.

Résumé

Les exploitations forestières en Suisse montrent des découverts croissants dans la gestion de la forêt durant les deux dernières décennies. Cette évolution suscite quelques inquiétudes dans la mesure où la gestion durable de la forêt doit aussi tenir compte de l'aspect économique. L'adoption de mesures de politique publique est nécessaire pour améliorer l'efficacité de production et réduire encore les coûts, tout en maintenant les services sociétaux à la population qui sont assurés par ces exploitations. La littérature sur la performance des exploitations forestières suisses qui a recourt à des méthodes statistiques et économétriques est limitée. Un certain nombre de références se basant sur des études de cas recommandent en conclusion l'adoption de mesures qui visent à accroitre l'efficacité dans la production de bois. Les rares études économétriques sur la performance productive se concentrent sur un seul output – la production de bois – sans considérer le rôle multifonctionnel de la forêt.

L'un des objectifs importants de la présente étude mandatée par l'OFEV est d'examiner la performance économique et technique des exploitations forestières suisses en prenant en compte explicitement le rôle multifonctionnel de la forêt. Cela est aujourd'hui possible grâce à la disponibilité de données comptables analytiques réunies depuis 2004 pour les 200 exploitations dans le Réseau d'entreprises forestières pilotes (REP) de Suisse. Les données financières et de production considèrent la production de bois (2ème échelon de production) qui a lieu dans le cadre des quatre principales fonctions forestières (production de bois, protection contre les dangers naturels, loisirs et détente, paysage biodiversité).

Les exploitations forestières, par hypothèses, prennent des décisions autonomes sur le niveau de production et l'utilisation de facteurs. L'efficacité technique d'une exploitation peut être évaluée par la différence relative qui existe entre les points de valeur observés du niveau des outputs et des inputs, et le point estimé correspondant à la frontière de production. Une autre manière d'analyser la performance est d'estimer économétriquement une fonction de coûts pour une seule ou plusieurs productions. Le recours à des fonctions des coûts permet également de mettre en évidence les coûts marginaux de production et l'influence des différents déterminants des coûts ainsi que l'existence d'économies d'échelle et la taille optimale d'une exploitation forestière.

Les principales questions de recherche ont été identifiées préalablement avec l'OFEV. Les objectifs fixés comprennent l'estimation des niveaux d'efficacité technique des exploitations forestières et l'identification des différents déterminants, tels que les contributions financières étatiques, le type de propriété ou le degré de diversification de la production et des services. L'étude contribue aussi à l'évaluation de la qualité des données pour des recherches à venir, en particulier par rapport aux différentes fonctions forestières.

Les résultats qui ont été obtenus sont dans une large mesure consistants à travers les différentes approches empiriques choisies. Les résultats sur **l'efficacité technique** suggère qu'en moyenne son niveau est relativement bas pour la production totale de bois, comme d'ailleurs pour celle des autres fonctions forestières. On peut en effet penser que les inputs comme l'emploi, les machines, ou même l'externalisation de prestations, pourraient être réduits de façon significative sans que la plupart des exploitations doivent réduire leur niveau de production. Ceci pourrait s'expliquer par l'hétérogénéité inobservée élevée des exploitations, mais aussi par des contraintes hors marché

imposées à ces exploitations. Le «benchmarking» – soit la comparaison systématique des exploitations - par rapport aux caractéristiques observées des exploitations montre par exemple que les exploitations efficaces ne doivent pas autant s'occuper de forêt protectrice, ou qu'elles se trouvent dans la région du Plateau. En outre, les résultats montrent que les exploitations peu diversifiées, c'est-à-dire celles qui se concentrent sur la production de bois, sont plus efficaces que les exploitations diversifiées. En effet, pour la période sous observation, les exploitations forestières dont la part des ventes de bois représente plus de 80% des recettes totales montrent un degré d'efficacité moyen significativement plus élevée que les exploitations dont les ventes de bois représentent moins de la moitié des recettes. En général, la situation géographique (région, topographie) apparait comme un facteur très dominant du comportement et de la performance technique des exploitations.

Dans l'ensemble, les exploitations comprises dans le REP exploitent les **économies d'échelle** existantes. L'analyse d'enveloppement de données (DEA) à travers toutes les fonctions forestières montre que presque trois quarts des exploitations forestières du REP opèrent à un niveau de production caractérisé par des économies d'échelle décroissantes (en termes de production de bois). En d'autres termes, en moyenne, le niveau de production de la majorité des exploitations se situe plutôt au-dessus du niveau pour lequel les coûts moyens de production seraient les plus faibles – c'est-à-dire le niveau technique « optimal » de production tel qu'il ressort de l'analyse. La production « optimale » d'une exploitation typique se situerait autour de 5'000 m3, ou en termes de surfaces forestières à 1'000 ha environ. Si l'on considère les différentes fonctions forestières de manière séparée, la taille « optimale » est plus basse. Par exemple, le niveau « optimal » de la production dans le cas de la biodiversité se situe à moins de 1'000 m3. Mais, ce seuil de production varie d'une région forestière à l'autre. Toutefois, il existe toujours une minorité relativement large d'exploitations plus petites qui pourraient bénéficier d'une croissance de leur taille, par coopération, ou fusion. Les mesures d'incitation existantes ne sont vraisemblablement pas suffisantes pour surmonter les coûts de transaction et les considérations stratégiques individuelles des propriétaires publics de forêts.

Sur le plan purement théorique, les **contributions financières** de la part de l'Etat peuvent contribuer à l'inefficacité, puisqu'elles réduisent également la pression du marché. Empiriquement, il est difficile de se prononcer sur le sens de causalité. L'approche non paramétrique montre que les exploitations efficaces tendent à recevoir moins de supports financiers (en pour cent des recettes). De l'autre côté, dans le cas de la fonction de production de bois uniquement, les contributions financières exercent un effet positif sur l'efficacité productive. Il n'est pas exclu non plus que certaines contributions à la protection de la forêt ou aux services rendus à la population augmentent, indirectement, l'efficacité de la production de bois. Sur le plan des coûts, les estimations empiriques indiquent que les contributions financières exercent un impact relativement important. Ce résultat n'implique toutefois pas des conclusions générales pour la politique forestière. En effet, il est tout à fait possible que les exploitations dont la production est relativement peu coûteuse reçoivent peu de contributions publiques parce qu'elles n'en ont simplement pas besoin. Malheureusement, les données disponibles ne permettent pas d'identifier les causalités dans chaque cas.

Quant à l'efficacité de production **par fonction forestière**, il apparait que la production de bois dans les forêts protectrices est la moins performante. Cela s'explique par le fait que la production de bois dans les forêts protectrices n'est par essence même pas l'objectif premier des exploitations. Les forêts protectrices se trouvent le plus fréquemment dans les régions des Préalpes et Alpes, dans lesquelles la croissance des arbres est nécessairement plus faible pour des raisons climatiques. A cause des conditions d'exploitation défavorables le niveau des ressources utilisées est comparativement élevé. Pourtant les résultats indiquent aussi l'existence de synergies entre la production de bois et les autres services rendus à la population par la forêt. En plus de l'exploitation d'économies d'échelle, la complémentarité des fonctions en termes de coûts constituent une raison de plus pour favoriser la fusion des exploitations et de la propriété forestière, ou du moins une collaboration plus étroite. A défaut, l'**externalisation** de la production est devenue de plus en plus fréquente pour réduire les coûts, ou pour une meilleure gestion de ressources de la part des exploitations forestière. Il apparait clairement que l'externalisation a un effet positif sur l'efficacité en termes de coûts

A ce jour, il n'existe un nombre limité de programmes fédéraux qui incitent à améliorer l'efficacité de production ou de réduire les cours de production. Ces programmes encouragent la coopération grâce à une participation aux coûts de la mise en œuvre et essaie d'augmenter l'efficacité dans la logistique et la planification en vertu d'une gestion durable de la forêt, y compris par le biais de contributions aux soins aux jeunes forêts. Face aux déficits menaçants, quelques mesures ont été prises pour pousser les propriétaires publics de forêts et les exploitations plus grandes à l'amélioration de leur performance dans la production de bois et les autres fonctions (good practice workshops, cercles de benchmarking, informations, formation et formation continue).

La forêt en Suisse croit et continue de s'étendre. Le potentiel durable de la production n'est actuellement pas exploité, la production de bois pour augmenter de façon significative sans pour autant réduire les ressources naturelles de la forêt à long terme. Augmenter la production dans le cadre donné du marché national (ou international) peut amener à une amélioration des opérations de production, mais il existe aujourd'hui de multiples contraintes et obstacles à surmonter, tels que la demande encore limitée pour le bois d'origine suisse, les processus de transformation inadéquats, une structure sous-optimales de la chaine de valeur, des coûts de transports élevés et plus récemment la valeur élevée du franc suisse qui encourage les importations et découragent les exportations. Aussi, il ne faut pas ignorer l'existence des fonctions non économiques et leurs interférences avec la production du bois. Il est certain que davantage de recherches sur l'offre et la demande dans les marchés de bois est nécessaire pour identifier les mécanismes qui sont susceptibles d'améliorer l'efficacité.

Nous remercions la section « Economie forestière et industrie du bois » de l'Office fédéral de l'environnement (OFEV) pour nous avoir donné l'occasion de travailler sur le sujet. Un remerciement spécial est adressé au chef de la section, Alfred Kammerhofer, et son suppléant, Matthias Kläy pour leurs commentaires et observations pertinents durant toute la durée du projet. Nous aimerions également témoigner notre gratitude envers les fournisseurs des données, l'Office fédéral de la statistique et l'Economie forestière Suisse, pour leur support. Nous remercions également les participants au workshop du 7 novembre 2012 organisé par l'OFEV, en particulier Roland Burri, Christoph Hartebrodt, Bernard Pauli, Oliver Thees et Willi Zimmermann, pour leurs commentaires utiles.

Les auteurs poursuivent actuellement leurs recherches sur l'économie forestières dans le cadre du projet « Comprendre le marché du bois: entre approvisionnement et multifonctionnalité », financé par le Programme national de recherche PNR66 « Resource bois » durant les années 2013 à 2015.

Summary

Swiss forestry firms show an increasing deficit in forest management over the last two decades. This development is worrying because the economic component of a sustainable forest management has also to be considered. Measures are indeed necessary in order to increase production efficiency and contain the costs while maintaining services for public welfare provided by these firms. The existing literature on the performance of Swiss forestry firms using statistical and econometric methods is scarce. Several analyses are based on case studies that recommend policy measures aiming at increasing the efficiency of timber production. The rare econometric studies on the performance of the Swiss forestry firms focus on one output – the production of timber – leaving aside the multi-functional role of forests.

One important objective of this study mandated by the FOEN is to examine the economic and productive performance of the Swiss forestry firms taking explicitly into account the multi-functional role of the forest. This is now possible thanks to the analytical accounting data collected since 2004 for a selection of 200 forestry firms (Swiss network of experimental forestry firms, or Réseau d'entreprises forestières pilotes – REP). The financial and production data set distinguishes, among others, the production of wood (2nd level of production) of the forestry firms that are conducted in the framework of the four forest functions (wood production, protection against natural hazards, leisure and recreation, biodiversity).

The forestry firms take, by assumption, autonomous decisions regarding the production levels and the factors used. The production efficiency of a firm can be estimated by the relative difference between the point representing the observed values of the inputs and outputs, and a corresponding estimated point on the production frontier. Another way of studying the performance is to estimate a single or multi-output cost function. The analysis of cost functions allows the estimation of marginal costs of production and the influence of various cost drivers as well as to determine the existence of economies of scale and the optimal size of a forestry firm.

The main research questions to be answered by the study have been defined beforehand together with the FOEN. These aims include specifically to estimate the efficiency levels of the forestry firms, and to identify the effects of different determinants, such as the financial contributions by public authorities, the type of ownership or the degree of diversification of the production and services. In addition, some effort is deployed to look into the potentials of economies of scales. The study also contributes to the assessment of the quality of the data for further research, in particular with respect to different forest functions.

The results reached are more or less consistent across the different empirical approaches. The results on **technical efficiency** suggest a priori a rather low average level for total wood production, as well as by forest functions. They suggest that inputs such as personnel, forest vehicles and even outsourcing of services could be substantially reduced in most of the firms without reducing production. This might be explained by the strong unobserved heterogeneity among firms but also partly by non-market constraints imposed on the firm. A benchmarking – the comparison among firms – with respect to the observed characteristics of the firms shows that, for example, efficient firms tend generally to fulfil less protection functions or are located in the Mittelland region. Moreover, the results show that non-diversified firms (that are focused on wood

production) are more efficient than diversified firms. Over the observation period, forestry firms with a share of sales of wood in total revenues of over 80% show a significantly higher average efficiency compared to the firms with less than 50% revenues from wood sales. In general, the location (regions, topography) seems to be a strong determinant of the behaviour and the production performance of the firm.

On average the firms included in the REP data set exploit the **economies of scale**. The Data Envelop Analysis (DEA) for wood production of all forest functions combined show that almost three quarters of the forestry firms in the REP data set operate at decreasing return to scale (in terms of wood production). In other words, on average, the production level for the majority of firms is likely to be above the level that potentially minimises unit production costs, i.e. the so-called "optimal" size or level of production that has been determined in this study. The "optimal" size of production for a typical firm is about 5'000 m3, and in terms of forest surfaces about 1'000 ha. When considering the individual forest functions, this "optimal" size is lower. For example, the "optimal" production level for the natural forest (biodiversity) is less than 1'000 m3. Also, the production threshold varies from one forestry region to another. Still there exist a large minority of smaller firms that might benefit most from an increase of size, by cooperation, or mergers. The existing policy incentives may not be sufficient to overcome transaction costs and individual strategic considerations of the public forest owners.

Theoretically, **financial contributions** by government may contribute to inefficiencies, as they also ease market pressure. Empirically, it is however difficult to determine the exact causality. The non-parametric approach shows that efficient firms tend generally to receive less financial support (in percentage of revenue). On the other hand, in the case of the economic function only, financial contributions seem to exert a positive effect on technical efficiency. It is also possible that contributions to protective projects or to support social welfare services of the forest enhance indirectly the efficiency of wood production. On the cost side, the empirical estimations show that the financial contributions exert a quite important impact on costs by influencing the decision-making behaviour of the firms. This result does not necessarily imply general forest policy conclusions. It might be the case that the relatively cost-efficient firms have relatively low public contributions because they do not need such assistance. Unfortunately, given the available data, it is difficult to identify the extent of causality effect in each case.

When analysing the efficiency by **forest functions** it appears that wood production in protective forests is generally the least efficient. This can be explained by the fact that wood production is by definition not the primary objective in protective forests. Protective forests are generally located in the "Prealps" and Alps regions where timber growth and the volume of production, due to climatic conditions, are generally low, and inputs, due to difficult harvesting conditions, are relatively high. However, the results point to certain synergies in the form of cost-complementarities between timber production and the other services in favour of public welfare. Besides eventually benefitting from economies of scales, cost-complementary between functions would be an additional rational for merger and fusion of firms and forest areas, or at least for close or closer collaboration. Instead, **outsourcing** has become increasingly popular as a mean to reduce costs and to improve the management of the available resources. Clearly, the extent of outsourcing has a positive effect on cost-efficiency.

Presently there are only a few incentive programs set up by the federal government aiming to increase production efficiency or to reduce production cost. These programs encourage cooperation by participating in the costs of setting up such cooperation and try to enhance efficiency in logistics or planning while taking into account sustainable forest management, notably by contributing financially to the costs of looking after young forests. In face of threatening deficits, some policy measures have been taken to induce public owners and relatively large firms to improve their economic performance in wood production and other forest functions (good practice workshops, benchmarking circles, information, education and training).

The Swiss forest is growing and expanding further. The sustainable timber harvesting potential is not exploited yet, and wood utilisation can be increased significantly without reducing the forest's natural resources. Increasing the supply within an established national (or international) market may lead to more efficient operations, but there are today several constraints and obstacles to overcome, such as limited demand for Swiss wood, inadequate supply channels, high transportation costs and in recent times the high value of the Swiss franc, favouring imports and making exports more difficult. Moreover, the presence of noneconomic functions and their possible interference with timber production cannot be ignored. Definitively, more research is required on both the supply and the demand side of wood markets in order to identify mechanisms that could enhance efficiency.

We would like to thank the FOEN section of Forest and Timber Industry for giving us the opportunity of working on this topic. Our special thanks go to Alfred Kammerhofer, the section's director, and his deputy Matthias Kläy for their comments throughout the project. We are also grateful to the data providers Federal Statistical Office (FSO) and the Swiss forest owner association for their support. We also thank participants of the FOEN's forest workshop on November 7, 2012, especially Roland Burri, Christoph Hartebrodt, Bernard Pauli, Oliver Thees and Willi Zimmermann for their helpful suggestions.

The authors will pursue their research on the Swiss forestry industry in the framework of the project "Understanding the wood market: between provisioning and multi-functionality", financed by the National Research Programme 66 Resource Wood from 2013 to 2015.

1. Introduction

The official forestry policy 2020 as stated by the Federal Council in 2011 follows a strategy of sustainable development trying to define and satisfy social, environmental and economic objectives, including land planning, protection of natural resources, biodiversity, protection against natural disasters, provision of space for leisure and relaxing, but also the supply of wood and other forest products[1]. It aims at creating the favourable conditions for an efficient and innovative forest industry.

Forest areas account for about 30% of the Swiss territory[2]. Forests are mostly publicly owned (70%). On average the 2'800 public institutions own 170 hectares, whereas the 244'000 private owners possess, on average, only 1.4 hectare. There are an estimated 2'475 private and public forestry firms, but only 200 of them work on large productive forests areas (above 1'000 hectares). A large proportion of the forestry firms are operating seasonally and or occasionally. The firms may outsource part or most of the harvesting to specialised forestry contractors. Total harvest in the last four years (2008-2011) fluctuates around 5.1 million m3 (3.3 million by public owners, 65%).

The Swiss forestry firms suffer from financial problems that are reflected in an increasing deficit over the last two decades[3]. The subsidized industry has raised public concerns calling for policy measures to increase production efficiency and contain the costs of producing wood while maintaining public services provided by these firms. The Swiss forestry firms operate in strongly varied environments with different complexities in production and organisation. Many of these differences result from structural differences that are beyond the usual characteristics such as size and production volume. There are a number of factors and constraints which contribute to difficulties in producing timber, some of them being imposed by the natural environment beyond the control of the industry operators, some may be related to the objectives of Swiss forest policy reflecting also the strong attachment of the population to the forest, and others may resort from an inadequate organisation and management of production and sales on the timber market.

Forestry firms in Switzerland are characterized by considerable heterogeneity specific to their location, topography, type of vegetation and other environmental factors. This heterogeneity is especially important if we consider in addition the multi-functional nature of forest services. A realistic picture of the industry's performance requires an account of all forest services and the forestry's contribution in maintaining them. These services are classified into four main groups according to the forest's functions: production (provision of wood resources), protection (of roads and villages in mountains and slopes), leisure and relaxation, and landscape/nature (natural beauty, biodiversity and environmental protection).

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[1] Conseil Fédéral, Politique forestière 2020, Feuille fédéral, no 48, 29 novembre 2011, pp. 8025-8048.

[2] See OFEV, Annuaire La forêt et le bois 2012, Bern 2012 (Yearbook), and the leaflet, FOEN, Forest and wood in Switzerland, Bern, 2010 for a general description of forest structure, exploitation, functions and policy in Switzerland.

[3] According to the Swiss forestry statistics, total expenses in wood production ("exploitation principale") exceeded for the first time its receipts (without contributions from third parties) in 1990 (hurricane Vivian). Since then, the deficits show an increasing trend: from an average of 23% (percentage of expenses) over the period 1990 to 2000 to 34/37% for the 4 years after hurricane Lothar in December 1999. During the period 2004 to 2011, the average deficits, not strictly comparable due to the 2004 revision of the statistics, amounts to 38%. Public contributions and net revenues from accessory activities reduce the deficit significantly, to 19% between 2000 and 2003, and to 8% on average thereafter. See OFEV, chapter 10 in: Annuaire La forêt et le bois, table 10.4, page 74, 2013.

Many of these factors are not directly observable or too complex to be taken into account as simple measures tractable in cost and production models. Therefore, a simple benchmarking analysis in using available accounting data that do not account for these differences might lead to biased efficiency estimates. An adequate analysis of costs can be used to identify groups of firms that are relatively more uniform hence reasonably comparable. Such “comparable” firms can then be analysed with benchmarking models.

The existing literature on the performance of Swiss forestry firms using statistical and econometric methods is scarce. A number of studies use cases studies in order to conclude on recommendations of policy measures aiming at increasing the efficiency of timber production[4]. Mack (2009) and Schönenberger et al. (2009)[5] are the first studies which applied econometric and statistical methods to the panel data provided by the former BAR data base set and maintained by Economie Forestière Suisse (EFS) on around 400 forestry firms located throughout Switzerland. The latter study also interviewed ten forestry firms in order to verify and possibly validate the empirical results.

The detailed analysis of the benchmarks through the Data Envelopment Analysis (DEA) method, which links the production level to the inputs, identified the characteristics of relatively efficient firms. The influence of environmental conditions, such as the location in a forest region, the productive forest area or the growth of the stock of wood, as well as decisions about subcontracting or the use of public contributions is tested econometrically in a second step.

Mack (2009) studied the performance of Swiss public forestry firms using the DEA technique and two econometric methods, i.e., the shifted ordinary least squares (SOLS) and the stochastic frontier analysis (SFA), to consider, among other, the relationship between technical efficiency and profitability. As might be expected, an increase in the efficiency of a firm generally improves profitability.

Both studies show that there is a strong potential for improvement in terms of efficiency for forestry firms. Moreover, and in general, there is still a possibility of exploiting economies of scale that would save factors and reduce costs. It is also shown that the bourgeoisie owners of firms are generally more efficient than other owners (municipalities, cantons). Finally, third-party services (outsourcing of production activities to specialized forestry firms) and work mandated by the other firms (third party fees) have a positive effect on technical efficiency.

The purpose of the research project mandated by the FOEN is to examine the economic and production performance of the forestry firms taking into account their multi-functional role. The efficiency estimates will be analysed and compared with the results of the previous estimates based on a single output (economic function). Further, a multi-output cost function is estimated. The estimation results will be assessed with respect to their plausibility and also the comparability of the estimated marginal costs. The empirical results may point to specific policy measures. For the first time, the data collected since 2004 for a selection of 200 forestry firms will be used in

[4] See for instance: Hofer, P. & J. Altwegg (2006), Geopartner, Lernen von erfolgreichen Forstbetrieben, Ergebnisse einer Untersuchung über die wirtschaftlichen Erfolgsfaktoren ausgewählter Forstbetriebe in der Schweiz, Bundesamt für Umwelt, Bern; Pauli, B. & B. Stöckli (2009), Kooperationen in der Schweizer Waldwirtschaft, Bericht von holz21, Bern.

[5] Mack, A. (2009), L’efficience des exploitations forestières publiques en Suisse, thèse de doctorat, Université de Neuchâtel. Schoenenberger, A., Mack, A. & Von Gunten, F. (2009), Efficacité technique des exploitations forestières publiques en Suisse, Strukturberichterstattung, No. 42, SECO, Bern.

applied statistical and econometric research on their economic and technical behaviour (REP Réseau d'entreprises forestières pilotes - Network of experimental forestry firms). The study also wants to contribute to assess the quality of the data for further research, in particular with respect to the different forest functions.

The rest of this report is organised as follows. Section 2 presents the research questions and the empirical methodology used to provide an answer. Section 3 discusses the data used and in section 4 we present the main results with respect to the main research questions: separately for the level of technical efficiency, the presence of economies of scale, the financial contributions paid to the forestry firms and finally the influence of organizational characteristics on the behaviour of the firms**.** Finally, in section 5 we provide some policy recommendations.

The present report summarises the methodologies employed and the findings of four technical contributions, which are inserted in the appendix of this report. This report can be read independently.

2. Research questions and methodology

This research pursues the previous studies summarised above on the technical performance and its determinants, but by employing partly different estimation techniques and above all a totally new data base. Table 1 below gives an overview of the main research questions and the methodology used. A crucial first stage has been to examine carefully the data base for its potential in answering the questions and for further research. Two different methodological and empirical approaches are used.

Mack (2012) uses the non-parametric method known as Data Envelopment Analysis (DEA). No hypothesis is done concerning the functional form of the production technology or the distribution of the random residuals. The forestry firms take, by assumption, autonomous decisions, particularly regarding the production and the factors used. They transform, given the existing technology, inputs (in particular labour and capital) into outputs (wood). DEA measures the efficiency by calculating the relative difference between the point representing the value of observed inputs and outputs, and a hypothetical point on the frontier of that same production. The method is then used to identify best practices (benchmarking) with respect to all observations, that is to say the production frontier, and thus to measure the efficiency degree (score) of each unit. To account, then, for the effect of the environment likely to influence the performance of the forestry firms, the efficiency scores obtained from the DEA analysis are regressed, in the second stage, on environmental variables, i.e., (exogenous) factors that are not or only indirectly under the control of a firm. In addition the method can test for the existence of economies of scale particularly if there are large differences in the scale of production of the forestry firms.

Besides traditional input factors (i.e., labour and capital) used in the process of wood production, environmental factors might influence the technical efficiency of a firm. These factors (e.g., climate factors, topographic factors, wood growth, contributions) are not traditional inputs (or outputs), and are supposed to be not (directly) under the control of the firm's manager. Different approaches exist in the framework of the DEA method allowing the integration of such environmental factors. Typically, the typical two-step approach performs in the first step an ordinary DEA analysis on inputs and outputs, followed by a regression analysis in the second step (several studies use ordinary least squares (OLS), others a Tobit model) which tries to explain the variation of the efficiency scores obtained in the first step by a vector of observable environmental variables.

The basic model (M1) for determining the technical efficiency of the firms is an input-oriented model containing one output (total annual wood production in m3) and four inputs: wood production personnel (hours), total forest vehicles (machine hours), third-party services (Swiss francs CHF), and administration costs related to wood production (CHF). M1 has been tested for the total wood production, i.e., all forest functions taken together, but also for each forest function individually. As the forestry firms are relatively heterogeneous in terms of size, the existence of variable returns to scale (VRS) is assumed. Model 2 is set up for a better comparison with the results found in the framework of the econometric analysis of costs in multi-output forestry firms. M2 consists of seven outputs (log or timber, firewood, industrial wood and other assortments; productive forest area for production, protection, leisure / nature and landscape; roads) and three inputs (working hours, i.e., wood production personnel; machine hours, i.e., total forest vehicles; third-party services).

Table 1: Research questions and methodology

Questions	Data, methodology and data/variables
1. What is the level and the evolution of technical efficiency of the forestry firms in general and with respect to the four forestry functions: wood production, protection, leisure and environment? 2. What are the factors influencing the level of technical efficiency? The following potential determinants are examined: - financial contributions ("subsidies") by the government - size of the forestry firms (areas, quantity of wood produced). What is the "optimal" size? - diversification, i.e. relative importance of the timber production (sales): pure wood producer (% of total turnover of wood sales > 80%), firms weakly diversified (50 to 80%), strongly diversified (30 to 50%), service supplier and producers of goods (< 30%); - type of ownership - operating results	Data Envelopment Analysis DEA (data: REP) Output: - total wood production, m3, or - 3 wood products and 3 forest areas, ha (depending on forest functions) + length of roads Inputs: - wood production personnel, hours - forest vehicles, machine hours - third party services, CHF - administration cost, CHF Benchmarking variables: - forest region - ownership - diversification - returns to scale - financial contributions Second stage regressions (forest functions): - wood growth - revenue - training - investments - financial contributions Cost functions (data: REP, Forest Statistics FS): - economies of scale (data: forestry statistics), by functions with 2 outputs (wood, area), depending on contributions, years, ownership, types of employment and regions - relationship, see below (data: REP)
3. What is the relationship between costs and output?	Explained variable: - total cost of production (excluding ancillary services), CHF Explicatory variables: Outputs: - 3 log productions depending on forest function, m3, and 3 public services (areas), ha, and length of roads, km2 - 3 log productions depending on forest functions, m3, and 3 non log productions, m3, depending on forest functions, and length of roads, km2 Other variables: - share of ancillary services in revenue - input price of labour and capital (residual) - forest region - financial (contributions, administration cost, outsourcing cost) - road and wood density
4. Are the REP/TBN data suitable to empirical analysis? What are their shortcomings?	Evaluation of the results

Farsi (2012) estimates a multiple-output total cost function. The “transcendental logarithmic” or “translog” cost function used embodies all assumptions and results of a cost minimisation model. It is a very flexible functional form which can be used easily, if the data required is available, in empirical work. In particular, this specific cost function allows for U-shaped average costs and is suitable for testing the presence of economies of scale. The cost function relates total production costs to the quantities produced, input prices and other variables which might influence the level of cost. In addition to applying the cost function approach to the whole panel of forestry firms, quantile regressions are used to study the variation of costs among different groups of forestry firms[6]. This permits to identify different classes of forestry firms with potentially different technical and economic problems.

The timber output is classified into three main categories, i.e. logs, firewood and industrial. The little remaining timber is included in the industrial category. The analytical accounting data of the REP classify timber production as well as the forest area into four functional categories, namely timber produced in relation with forests with productive, protective, leisure and nature/landscape functions. However, the third and fourth categories (leisure and nature/landscape), especially the latter, are generally small and a number of firms in the data set do not possess forestry area in those categories. Therefore, these two categories are combined into one group. Moreover, the production level of fire and industrial wood is relatively small, so that only two large groups of wood by functional categories are retained (logs and non-log wood).

It is important to note that the Swiss forestry firms increasingly use outsourcing contracts for their timber production. That is, a substantial part of costs is the purchase of third-party services. As shown in Table 2, a typical average company’s cost share of third-party services is about 27%. Outsourcing can go up to more than 90% of the activities related to wood production. The outsourcing costs are non-labour costs which are included in the residual cost of “capital”. Note that because of limited data the non-labour cost in the model is an aggregate input including all costs which are not related to the labour employed by the forestry firm. A series of preliminary regressions has been performed in order to identify the variables that have a better explanatory power. These variables include fixed effects for years and regions. However, the year dummies were never statistically significant.

[6] Linear regression is a statistical tool used to model the relation between a set of predictor variables and a response variable. It estimates the mean value of the explained variable (cost) for given levels of the explanatory variables (volume produced, input prices, regions, etc.). A more comprehensive picture of the impact of the explanatory variables on the production costs can be obtained by using “quantile regressions”. Quantile regression models the relation between a set of variables and specific percentiles (or quantiles) of the variable to be explained. It specifies changes in the quantiles of the response. In linear regression, the regression coefficient represents the increase in costs generated by a one unit increase in the explaining variable associated with that coefficient. The quantile regression parameter estimates the change in a specified quantile of the explained variable produced by a one unit change in the independent explanatory variable. This is reflected in the change in the size of the regression coefficient.

Table 2: Descriptive statistics (655 observations from 195 forestry firms)

	Variable	Mean	Standard-Deviation	Minimum	% of zero values [i]	Maximum
A^t	Total forest area ('00 ha)	11.035	11.008	0.500		73.000
PA^t	Productive (harvestable) area ('00 ha)	9.564	9.125	0.500		73.000
W^t	Total timber production ('000 m^3)	4.894	3.402	0.086		18.071
PP	Production possibility of timber ('000 m^3)	5.181	3.687	0.400		20.000
	Timber production by wood category ('000 m^3)					
W^1	Log	2.847	2.222	0.000	(0.2%)	13.763
W^2	Firewood	1.209	1.193	0.000	(5%)	7.403
W^3	Industrial [ii]	0.713	1.016	0.000	(14%)	6.783
	Forest area by the assigned primary function ('00 ha)					
A^1	Production	4.790	4.819	0.000	(15%)	26.070
A^2	Protection	5.084	10.659	0.000	(53%)	73.000
A^3	Leisure/Nature	1.157	2.124	0.000	(45%)	14.250
	Log production by the assigned primary function ('000 m^3)					
L^1	Production	1.941	2.098	0.000	(21%)	12.207
L^2	Protection	0.794	1.511	0.000	(58%)	11.018
L^3	Leisure/Nature	0.111	0.396	0.000	(81%)	5.114
	Non-log production by the assigned primary function ('000 m^3)					
N^1	Production	1.644	1.779	0.000	(21%)	9.236
N^2	Protection	0.334	0.637	0.000	(59%)	4.711
N^3	Leisure/Nature	0.070	0.281	0.000	(80%)	4.473
	Input factor prices					
P^L	Labour (CHF/hr)	46.34	12.21	21.94		105.73
P^K	Non-labour (CHF/ha) [iii]	489.04	259.57	41.97		1727.24
	Revenues and costs					
C	Total cost (CHF) [iv]	589'748	459'912	14'693		4'239'098
C^{anc}	Cost share of ancillary services (%) [v]	2.76	4.12	0.00	(25%)	31.29
S^{sub}	Revenue share of public contributions (%)	27.78	20.25	0.00	(2%)	91.84
S^{ad}_m	Share of administration costs (%)	13.04	6.18	0.00	(0.2%)	65.03
S^{out}	Share of outsourcing costs (%)	27.28	18.56	0.00	(1%)	96.58
	Infrastructure and forest density					
R	Length of roads (m/ha)	78.517	71.868	0.000	(4%)	542.000
D^w	Wood density (harvest possibility) m^3/ha[vi]	6.54	3.56	0.34		23.68

Noted: i) % of observations with zero value is in parentheses, ii) Includes non-classified types; iii) Per forest's productive area; iv) Excludes costs of ancillary services; v) of total costs plus ancillary costs, vi) Per total forest area.

Source: Farsi (2012)

Krähenbühl (2012) applied the same framework to the data of the Swiss Forest Statistics which contains basic information on a very large number of forestry firms. The main purpose of this contribution is to test for the presence of economies of scale. The cost model assumes to follow a translog cost function containing two outputs only: wood, which is defined as the sum of all types of wood produced, and area, which is the total forest area exploited by the firm (i.e. addition of productive and non-productive forest surfaces). These estimations are a first attempt in using the available data for assessing various cost factors, the economies of scale as well as variations across the five forestry regions. The lack of data on specific factors such as input prices might lead potentially to an omitted-variable bias. The results are therefore to be taken with caution.

The estimations indicate large variations of marginal costs across regions, but also strong variation in the economies of scale. The estimated patterns are in general similar to those estimated with the REP data. Although the preliminary results obtained when using the Forestry Statistics in simple econometric models, subject to potential improvements, illustrate the usefulness of the data and the need for further analysis.

Finally, **Farsi et al. (2012)** discusses the use of a purely statistical approach for identifying types of forestry firms[7]. By definition, this approach is based on an uninformed methodology that attaches the same importance to all characteristics and does not consider the importance of economic and technological constraints. Alternatively, there are two approaches to tackle a typological analysis: One refers to multivariate analysis (such as cluster analysis) based on a selection of observed variables that could represent the production complexity in different forest areas. This complexity might be environmental but also organizational.

A more elaborate alternative is an econometric cost model with heterogeneity of parameters (such as quantile regressions) that can identify the typologies based on observables but also on the unobservable differences in their impacts on costs, such as complexity of the environment. The typologies and their number can vary depending on the variables included in the model specification. Given the limitation of econometric models with respect to the number of observations (number of firms in the sample) a tractable model, such as a cost function, will include a limited number of output variables defined from aggregating small output categories. The omitted variables will therefore contribute in what is identified as structural heterogeneity. The present research project does not give an answer to the question of typology, but constitutes a first step towards examining this question on the base of the REP data.

[7] It presents a critical view on the use of Principal Component Analysis (PCA) as a way to find, statistically, a meaningful typology of the forestry firms, as developed by the FVA on the demand of the FOEN. See Nagel, Ph., Hercher, W. & Hartebrodt, Ch., Typologisierung des Forst-Testbetriebsnetzes der Schweiz, FVA - Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg, Abschlussbericht vom 31.07.2012.

3. Data

The main data base of the Réseau d'exploitations forestière pilotes (REP or TBN (Testbetriebsnetz) in German), extracted for this FOEN project by the Swiss forest owners association (WVS), and made available by the Swiss federal statistical office (FSO), contains 229 different firms over a 4-year period (2007 to 2010) initially including 88 variables. The variables concerning operating revenues, costs, output and inputs are made available by the detailed analytical accounts of the participating forestry firms. Most of these variables are divided into the four forest functions: production (WW), protection (SW), leisure (EW), nature and landscape (N&L). The annual data consists of 200 firms per year (excepting 2008 that includes 202 firms). It is important to note that the firms are not identical across the four years. For 175 firms data is available for the entire 4-year period (balanced panel). For 19 firms data is available for one single year only, 22 firms are present over 2 years, and 13 firms appear during 3 years. The following table lists the number of firms in different years and by four forestry regions. In table 2, the few firms located mainly in the north of the canton Ticino (South of the Alps) are integrated in the Alps region.

Table 3: Number of firms with available data in TBN

Year		2007	2008	2009	2010
Total firms	229	200	202	200	200
1 year	19	6	1	2	10
2 years	22	11	14	11	8
3 years	13	8	12	12	7
4 years	175	175	175	175	175
Alpen	196	47	49	49	51
Jura	217	54	55	55	53
Mittelland	252	62	63	63	64
Voralpen	137	37	35	33	32

Source: Mack (2012)

The initial TBN sample shows some important discrepancies in data. Focusing on main variables such as costs and a number of physical variables such as the length of roads or areas that should not show a substantial change over the four years, the data set includes a number of cases with suspicious values. Moreover, some inconsistencies have been identified in the recorded numbers of input factors (employees, vehicle hours and 3rd party costs). If we exclude these cases from the data, the size of the samples is reduced. The number of remaining observations depends on the included variables. For instance if we focus on a balanced panel – i.e. in which the same firms appear over the entire observation period - with at least two non-zero inputs, the sample will include 149 firms (596 observations). On the other hand, if we consider a cost function with unbalanced panel data but exclude the cases with suspicious values for roads and areas, the final sample will include 195 firms (655 observations). Farsi (2012) excluded observations with missing values for wood production and costs. The exact number of observations with missing values varies depending on the considered variables. In order to minimize the excluded records the authors conducted a correction procedure for variables that are more or less time-invariant. The final sample covers 195 firms and includes 655 observations with non-missing values for all included variables.

The technical reports in the annex present descriptive statistics of the data set retained by the authors. An interpretation and a descriptive analysis of the REP data for the period 2008 to 2010 can be found in the recent report edited by the FOEN et al.[8]. The overall assessment of the REP-data is rather positive. The quality of the data is sufficient for a valid analysis of costs and efficiency. This expectation is confirmed by the quality of the results which have been obtained.

Krähenbühl (2012) tries to assess the economies of scale by using the data extracted from the Swiss Forestry Statistics (SF) which contained basic information concerning 1'971 firms over a 7-year period, from 2004 to 2010. The data encompass productive and non-productive area, production of different types of wood, region and type of owners. The available information also includes some of the most important financial information: total costs and revenues of the firms, as well as financial contributions and outsourcing costs. The SF statistics have existed for a very long time and information is available well before 2004. However, the study focuses on this period 2004 to 2010 only because the methodology of the statistics has changed in 2004, which makes it difficult to reconcile the data. Out of the 1'971 firms, 66 were completely removed from the sample because either costs, total production of wood, or revenues were equal to zero. Observations with no revenues were also dropped since the ratio of subsidies over revenues is computed and used as an independent variable. The number of firms in the final data set decreased from 1'624 in 2004 to 1'457 in 2010, totalling 10'857 observations. The numbers of observations for each forestry region are sufficient to create region specific regressions.

The assessment of the available micro-data is rather positive. In fact, the quality of the TBN data is sufficient for a valid analysis of costs and efficiency. This expectation has been confirmed by the overall consistent statistical and econometric results. In particular, comparing the results across several model specifications with and without potentially incoherent values, the number of suspicious data decreases over time, suggesting an amelioration of the reporting and collection processes through time. The TBN data cover however well organised and larger publicly owned forestry firms operating over the whole year in comparison with the very large number of small public and private firms also included in the yearly survey of the forest statistics.

[8] Office Fédéral de l'Environnement (OFEV) et al. (2012), Réseau d'exploitations forestières de la Suisse: Résultats pour la période 2008 – 2010, OFS, Neuchâtel.

4. Main Results

In this section the main results of the papers written for this research project are presented and summarised. This section is divided into four subsections respectively on: the level of technical efficiency, the presence of economies of scale, and the impact of financial contributions paid to the forestry firms. Other factors which influence the behaviour of the firms are presented in the last subsection devoted to further results.

4.1 Technical efficiency

Table 4 reports some of the estimates of the overall level of technical efficiency of the Swiss forestry firms. It indicates an average efficiency of 58.9% in 2007, decreasing to less than 53% in 2009, with a slight upturn for 2010. The relatively low efficiency scores indicate an important potential for increasing efficiency. This result is confirmed by some very low minimum scores that can be observed (around 10%). About half the firms have efficiency scores below 50%.

Table 4: Efficiency scores (DEA, variable returns, M1)

Year	N = 596 (observations)	Mean	Median	Standard deviation	Minimum	Maximum	Number of firms ≥50%	Number of efficient firms
2007	n=149	58.9%	51.0%	29.9%	7.2%	100%	79	36
2008	n=149	54.9%	46.8%	27.9%	11.1%	100%	71	30
2009	n=149	52.5%	46.2%	26.8%	10.6%	100%	64	24
2010	n=149	53.6%	47.1%	27.2%	8.6%	100%	68	22

Source: Mack (2012)

The efficiency scores estimated by forest functions are the following: the efficiency scores for economic forests (production function) decrease from around 71% in 2007 to less than 62% in 2009, before slightly increasing again; the scores are relatively low in the case of protective forests fluctuating around 51% over the four-year period. The efficiency of wood production in leisure forests varies between 67% and 76%, and the estimates for the low level of nature and landscape wood production start at a relatively high level in 2007 (81% and decreasing to less than 71% in 2010). According to these results, inputs (wood production personnel, forest vehicles, third party services, administration cost) could be reduced by at least 20 to 25% in most of the firms without reducing production.

These estimates overstate the degree of inefficiency as other factors are likely to influence its level. The impact of most of the firms' characteristics is assessed first by benchmarking the efficiency scores obtained by the DEA. Second, the scores are regressed on the few variables, which are available for wood production of all four forest functions.

The benchmark analysis of the efficient and relatively inefficient firms with respect to different characteristics of the forestry firms is likely to show which factor would contribute to the above average efficiency. For instance, poorly diversified firms are more efficient than diversified firm (table 5). Over the whole period, firms with a share of sales of wood in total revenues of over 80% show an average efficiency of 62% compared to the firms with less than 50% revenues from wood sales (average score below 52%).

Table 5: Efficiency and diversification (2007-2010)

	Number of firms	% of all firms	Average efficiency	Average profit WP (CHF)	CHF/ productive ha	CHF/m3	Total average profit (CHF)
≥80%	105	17.6	61.4%	-65'529	-69.2	-11.3	-102'710
≥50% and <80%	322	54.0	54.8%	-21'189	-21.4	-3.7	-90'476
≥30% and <50%	129	21.6	51.6%	-79'451	-90.7	-21.6	-228'734
<30%	40	6.7	51.0%	-70'117	-121.7	-36.9	-140'375

Source: Mack (2012)

Farsi's (2012) analysis confirms the results obtained in terms of costs. His results indicate a positive and significant cost effect for ancillary services, suggesting that these activities represent an additional burden for forest companies. Given the low average share of these activities (less than 5%) the effect is not considerable for typical companies. However, noting the relatively high share of annex activities in certain firms this burden could be substantial. For instance, the results indicate about 20% additional costs for a company that allocates about 10% of its resources on ancillary activities.

The benchmarking analysis suggest other factors which might increase the efficiency of the wood production process besides the fact that, by definition, efficient firms use less working hours, less machine hours, have lower administrative costs, and do more outsourcing than the least efficient ones (efficiency scores inferior to 25%):

Efficient firms tend generally

- to have a smaller productive area in protective forests,
- to fulfil less protection function (in terms of wood production in protective forests),
- to be located in the Mittelland,

as well as,

- to receive less contributions (as a percentage of revenue), and
- to sell more standing timber and produce more round wood.

The last two factors which characterise efficient forestry firms may also be the results of their behaviour. Especially for those characteristics, it might be that the causal relationship is reversed, i.e. for instance in some circumstances it is because the firms are less efficient that they get more financial supports from the state, and not the other way round.

Surprisingly, the forestry firms owned by "Bürgergemeinden" or "Korporationen" [9], compared to the firms belonging to the political municipalities (communes), tend to be less efficient. This result

[9] These peculiar institutions which exist in half of the cantons are owned by the people who are citizens of a village or a town, excluding the other residents of Swiss nationality who are not citizens of the local community. The historical origin

contradicts the results obtained in previous studies using a different data set (BAR data). For Krähenbühl (2012), the private owners tend to be more competitive. Mixed private/public ownership, compared to pure public ones, seems to be also generally more costly, except in the Alps region where the impact of public ownership on total costs is significantly positive. On the impact of ownership further research is required.

The impact of the work done for third parties (measured as the corresponding share in total revenue), training and investment expenses, total wood growth and public contributions on production efficiency is tested by regression (the only variables available by function are revenues received for work and financial contributions, see table 6). Referring to total wood production across all functions, a negative impact on production efficiency is found for the first three variables. Services supplied might be of various kinds, not necessarily in wood production, and lower productivity. Training expenses might not be related directly to productivity aspects of wood production (e.g. security issues, management training). Investments might show their positive effects only in the long term. Some of them might have only a distant connection to productive capacities.

Table 6: Second-stage regressions (M1/M2)

	Wood growth	Revenues for work	Training expenses	Investment expenditure	Financial contributions (“subsidies”)
Total wood production	ins/+++	---/---	---/ins	---/--	ins/---
Production	ins/++	ins/-	---/-	---/--	+++/+++
Protection	ins/++	---/---	---/--	---/--	---/ins
Leisure	ins/++	--/---	---/ins	---/---	ins/ins
Nature, landscape	ins/ins	ins/--	ins/ins	---/---	ins/ins
ins: insignificant; ---, --, - negative significant at 1%, 5%, 10%; +++, ++, + positive significant at 1%, 5%, 10%					

Source: Mack (2012)

By forest functions, i.e. analysing specifically the effect of revenues received and contributions by forest functions, the results are similar with the exception of financial contributions by government. It seems indeed that subsidies exert a positive effect on efficiency for the production function[10].

For the second model incorporating seven outputs instead of only one, the results are similar with the exception of total wood growth and contributions received. Total wood growth now exhibits a significant positive effect on overall efficiency, whereas contributions show a significant negative influence; moreover, the negative effect of training expenditures on efficiency is not significant anymore. For the individual forest functions, the explanatory power of the models sharply decreases, excepting for the protection forest. Here it appears that training expenditures have

was the obligation of the communes to take care of its poor citizens. As a consequence, the citizens set up an organisation which engaged in economic activities in order to finance the social assistance. Today, the Bürgergemeinden may still decide who can become a citizen and pursue some social activities. These citizen organisations are financed by the returns on regional economic activities (e.g. in forestry, agriculture, tourism).

[10] Note that the explanatory power of the regressions is very low, e.g., only 12% respectively 23% of the variation of the efficiency scores for total wood production can be explained by the variables used in the model.

again a significant negative impact on efficiency whereas contributions do not exhibit any significant effect.

4.2 Economies of scale

The DEA results obtained by Mack (2012) show that for all forest functions combined, almost three quarters of the forestry firms in the REP data sate operate at decreasing return to scale (in terms of wood production). In other words, on average, the production level for most firms is likely to be above the level which potentially minimises unit production costs (the so-called "optimal" size or level of production)[11].

Table 7 reports the results of the returns to scale analysis for model 1 (M1) by indicating the percentage of firms concerned by increasing or decreasing returns to scale for the whole period analysed (2007-2010), and for all forest functions taken together (total) as well as by forest functions. Three quarters of all firms produce at a level which is above the "optimal" size. The same reasoning applies when looking at the economic and protection functions. For instance, producing (on average) 1'806 m^3 in an economic forest seems to be not sufficient for reaching this size, but producing 4'979 m^3 seems to be too much. On the other hand, firms seem to be "too small" on average when looking at leisure and nature & landscape functions. Table 7 also shows the average productive forest area for firms with increasing or decreasing returns to scale.

Table 7: Returns to scale DEA (M1)

	Increasing returns to scale (IRS)	**Decreasing returns to scale (DRS)**	**Average production (m3) IRS**	**Average production (m3) DRS**	**Average productive forest area (ha) IRS**	**Average productive forest area (ha) DRS**
Total	**26.3%**	**73.7%**	**2'720.2**	**5'903.3**	**615.2**	**1'042.7**
Min / Max			*368 / 9'658*	*824 / 17'653*	*50 / 2'607*	*139 / 5'810*
501 (economic function)	20.0%	80.0%	1'806.2	4'979.2	385.3	592.9
Min / Max			*0 / 8442*	*25 / 17482*	*5 / 2'607*	*9 / 2'607*
502 (protection)	24.6%	75.4%	808.3	2'935.0	311.2	975.1
Min / Max			*0 / 5'226*	*28 / 1'4191*	*1 / 1'914*	*1 / 5'156*
503 (leisure)	73.2%	26.8%	58.7	1'449.7	69.1	192.3
504 (nature & landscape)	78.6%	21.4%	100.0	717.6	142.3	209.5

Source: Mack (2012)

For example, all forest functions taken together (total), it seems that the "optimal" size (in terms of productive forest area) lies in between 615 ha and 1'043 ha.

[11] As it is reported below, Krähenbühl's (2012) results when using the exhaustive survey of Swiss forestry firms of the Swiss forestry statistics suggest that an increase, on average, of the size of the firms would decrease costs, but most probably at different degrees depending on the regions. These different results are due to the much larger share of small and very small public and private firms in the survey. On contrary, the REP data base includes relatively larger public firms operating mostly throughout the years.

For Model 2 (Mack, 2012), when seven outputs and three inputs are considered, producing on average 2'262 m^3 of wood seems to be not sufficient for reaching the cost minimising size, whereas producing 5'957 m^3 seems to be a too large quantity (areas between 402 and 1'099 ha).

From the estimated cost functions, Farsi (2012) calculated output elasticities for the transformed output variables. Elasticities represent the effect of a proportionate change in the explanatory variable on total costs measured in a proportional manner, usually calculated at the corresponding sample means. Table 7 provides a list of output elasticities estimated according to the two different models. The figures indicate that output elasticities vary considerably across firms.

The model 2 indicates a more or less similar elasticity with respect to logs and firewood, but a lower effect of industrial wood. These numbers suggest for example that a 10% increase in logs or firewood production increases total costs by about 2% on average. The same increase in industrial wood production causes, on average, about a 1% increase in costs. The public service functions show a greater variation. Namely, a 10% increase in productive area implies about a 3% increase in costs, whereas a similar increase in protective areas induces about a 4% increase in costs. The lowest effect can be assigned to forest with leisure/nature function in which a 10% increase in area corresponds to only 0.6% extra costs. Finally the cost effect of roads is relatively high: a 10% increase in the length of roads results in about a 1.6% increase in total costs. Overall, the elasticities obtained from model 2 suggest that the protective function is the most costly function, followed by the maintenance of the productive forest. The production of wood (logs and firewood) comes only at the third place, followed by maintenance of roads and the production of industrial wood. Finally the cheapest function is leisure/nature.

Table 8: Output elasticities based on Box-Cox models

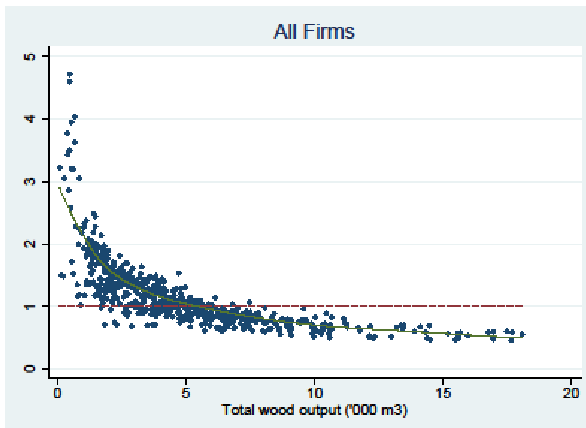
Output elasticities at corresponding sample means	Model 2	Model 4
W1: Wood production (logs)	0.190	_
W2: Wood production (firewood)	0.205	_
W3: Wood production (industrial)	0.105	_
A1: Public service (productive forest)	0.294	_
A2: Public service (protective forest)	0.401	_
A3: Public service (leisure/nature/landscape)	0.061	_
L1: Log production (productive forest)	_	0.316
L2: Log production (protective forest)	_	0.271
L3: Log production (leisure/nature/landscape)	_	0.111
N1: Non-log production (productive forest)	_	0.379
N2: Non-log production (protective forest)	_	0.148
N3: Non-log production (leisure/nature/landscape)	_	0.087
R: Public service (roads)	0.155	0.190

Source: Farsi (2012)

Model 4 differentiates the output elasticities with respect to the type of wood and the forest function. The values of output elasticity indicate the highest effect for production in productive forests: a 10% increase in log and non-log output result in 3.2% and 3.8% cost increase respectively. Production in protective forests has the second rank in costs with an elasticity of 2.7% for logs and 1.5% for other production. Finally, the cheapest production occurs in the forest with leisure/nature functions with elasticity of 1.1% and 0.9% respectively for logs and non-log production. These results are all intuitively explainable by the fact that the timber production is focused in productive areas. Higher density of production implies higher elasticities.

The estimated rate of economies of scale (ES) based on model 2 is shown in figure 8 below[12]. This rate is calculated for each observation. The values of ES are plotted against the total production volume and the forest area. These figures indicate that overall the optimal scale of production is at about 5'000 m3 production per year with a forest area of about 1'000 hectares. However, firms specialised in public service reach their optimal size between 2'000 and 3'000 hectares at a scale more than twice compared to other forestry firms. This result is consistent with the fact that the public-service companies have relatively low wood production volumes.

Figure 9: Economies of scale indicator for Jura and Mittelland (forest statistics)



Source: Farsi (2012)

The estimated rate of economies varies among different companies. However, a typical average company in the TBN sample exploits all the economies related to scale. There are obviously also small companies that can benefit from expanding their size through merger or joint activities with similar firms.

Krähenbühl (2012) shows that the results for the economies of scale – the evolution of total costs with respect to the outputs - in the different regions are not similar, in particular for the forest surface output. His results suggest that increasing size of Swiss forestry firms would decrease costs, but most probably at different degrees between regions as firms face different environments. Note however that his results are preliminary and suffer possibly from missing variable bias (e.g., no factor prices).

[12] The indicator of economies of scale (ES) corresponds to the inverse of the sum of all ratios formed by the changes of costs (numerator) and the changes of each of the outputs (denominator). If ES < 1, there is presence of economies of scale, if ES > 1 there are diseconomies of scale.

4.3 Financial contributions

Swiss forestry firms are confronted to a number of factors which do not favour efficient operations including small size, high transaction costs or public ownership[13]. By far not all forestry firms (or forest owners) are profit maximising. In addition, services to the public are often not accounted and paid for separately. Most of the forestry firms are publicly owned, by communes, some by cantons and the Confederation. The operations and budget of forestry firms are often relatively small at the local level, so that a possible operating loss in wood production is covered automatically by the local authorities.

Theoretically, financial contributions by government may contribute to inefficiencies, as they may ease the market pressure. In all these circumstances, management resources might be devoted to seek additional contributions instead of investing those resources in increasing efficiency. On the other hand, it is also possible that contributions to protective projects or the provision of public services of the forest enhance indirectly the efficiency of wood production.

The effect of the subsidies depends also on their design and the conditions at which they are attributed[14]. For instance, in the aftermath of Lothar in 1999, contributions have been given to projects in forest areas most hit by the hurricane in order to accelerate the elimination of the fallen trees. Those lump-sum subsidies did in general not cover the costs of the projects which have been submitted. The costs exceeding the financial contributions had to be paid by the firm. In this case, the lump-sum subsidies have limited, but not eliminate, the possibilities of inflating costs compared to subsidies calculated, e.g. as a proportion of the costs. However, it cannot be excluded that, in particular when production capacities are fully used in the short run, subsidies supported more costly projects. Empirically, it is then difficult to know in which direction the causation goes. For instance, the share of public contributions in revenues might be higher in firms which have higher cost. In this case, a positive correlation between subsidies and costs does not necessarily imply that the subsidies have a negative effect on efficiency.

In his benchmarking analysis, Mack (2012) suggests that efficient firms tend generally to receive less contribution in percentage of revenue. On the other hand, in the case of the economic function, subsidies seem to exert a positive effect on technical efficiency[15]. Krähenbühl noted that the impact of the percentage of subsidies over revenues is throughout all functions significantly positive. Again, this does not mean however that subsidies increase costs, as no causal

[13] For an overview of the structural problems and the changes in the technical and societal challenges faced by the Swiss forest industry, as an economic activity, see Pudack, T., Ansatzpunkte für den Strukturwandel in der Schweizer Forstwirtschaft, in: Thees, O. & R. Lemm (editors); Management zukunftsfähige Waldnutzung, Grundlagen, Methoden und Instrumente, VDF, Zurich, 2009, pp. 43-63.

[14] With the introduction of the new system of financial equalisation and division of tasks between the Confederation and the cantons in 2008, subsidy policy has stopped to be cost-oriented and based on individual projects. It is now service oriented in the framework of four-year agreements with the cantons, which also contribute financially to the programmes. Two third of the federal contributions are devoted to protective forest programmes and structures. The care of young forests, which may reduce, in the long run, harvest costs, is also financially supported by the federal government (and the cantons), which may reduce, in the long run, harvest costs.

[15] Açikgöz Ersoy, B. and J.A.K. Mack, "Relation between the Efficiency of Public Forestry Firms and Subsidies: The Swiss Case", in: Klatte, D., H.-J. Lüthi & K. Schmedders (eds.), Operations Research Proceedings 2011, pp. 121-126, Springer, Heidelberg, 2012. The analysis shows that in the long run (1998-2006), public subsidies appear to have a strong positive impact on efficiency. Moreover, total wood growth, revenues received by forestry firms, and training expenditures, also have a positive effect on efficiency. On the other side, investments have a small but significant negative effect on technical efficiency.

relationship is made here, but simply that subsidies go to those who incur the relative highest total costs.

Public contributions show a negative impact on cost-efficiency. The estimated coefficients suggest that for instance, any 10 percentage point increase in public contribution's revenue share is associated with a 2 or 3 per cent increase in total costs. Given the shares observed in the sample, a difference of 10 percentage points in contributions is quite plausible. Therefore the undesirable impact of public contributions is fairly considerable. In contrast, the share of administration costs and the extent of outsourcing have both positive effects on cost-efficiency. For instance, a 10 percentage point increase in these costs can be associated with a 10 percent decrease in total costs. This result implies that the firms that spend more on administration costs (including management, training etc.) as well as those that have a larger outsourcing share are comparatively more efficient in terms of total costs.

Taken literally, these results might be taken to imply that total costs can be decreased by cutting public contributions and expanding administration costs (management and training activities) and outsourcing. However, it is important to note that the estimated effects cannot be considered as conclusive one-sided causal effects. The empirical evidence, while suggesting significant correlation effect, does not necessarily imply general policy conclusions. In other words, it might be the case that the relatively cost-efficient companies have relatively low public contributions because they would not need such assistance. They also might have higher administration costs because they are relatively more capable to expand their management and training activities. As for outsourcing costs, it is important to consider that given that outsourcing might be quite high in many cases, the apparent efficiency in companies with high outsourcing might be related to the economies of scale of third-party providers. Unfortunately, given the available data, it is difficult to identify the extent of causality effect in each case. However, the directions suggested by the results are against high and untargeted public contributions while favouring outsourcing and greater administrative costs, e.g. better management.

4.4 Further results

Outsourcing

Forest companies are characterized by a great variation in outsourcing (Farsi, 2012). The share of outsourcing while being about 30% on average varies from about 0 to about 100 % of the firm's expenses. About half of the companies in the sample outsource more than a quarter of their activities (measured in costs), and about 10% outsource more than half. Any adequate analysis of costs and performance should account for these differences. The benchmarking analysis in Mack (2012) suggests that relative efficient firms generally outsource more than the least efficient ones (efficiency scores < 25%).

Regions

The forestry firms in the Alps are about 25 to 50% more costly than in other regions (Farsi, 2012). This result is generally confirmed by all the data sets available to us. The difference can be explained by the difficulty of access and operation on mountain slopes. This outstanding difference in costs suggests that in analysing the performance, the forestry firms located in the Alps should be considered separately. The harvest and production in areas with a higher density of road per hectare of forest and also higher wood density is on average less costly. This result can be explained by the lower marginal cost of access in areas with a high density of roads and trees. In fact, these areas represent a lower cost of access to one cubic meter of timber.

Marginal Cost

Farsi (2012) has identified the marginal cost of timber production for a typical median company but also for four other representative cost deciles (quantile regressions). Marginal cost measures the additional cost of an additional unit of output. Generally, higher marginal costs represent higher unit costs or average costs. If the marginal costs are constant across different firms, this would point that firms have a similar complexity of production, including production technologies and environmental factors. The analysis indicates however considerable differences in marginal costs suggesting that the forestry firms do not represent similar complexity. The forestry firms in the sample show a great degree of unobserved heterogeneity in marginal costs. It is likely that these cost differences are not due to differences in their performance. These differences are probably related to environmental and other factors that are beyond the firm's control. The greatest variation in marginal costs is observed in timber production and maintenance function in protective forests but also in forests whose main function is the leisure/nature function**.** In terms of type of wood, the firewood production shows the highest degree of heterogeneity in marginal costs.

The marginal costs for a median company are estimated as follows: 77, 116 and 84 CHF/m3 respectively for logs, firewood and industrial wood; 98 and 108 CHF/m3 for log production in productive and protective areas respectively; and 95 and 152 CHF/m3 for non-log production in productive and protective areas respectively. Similarly, median marginal costs of public-service functions are estimated as follows: 116 CHF/ha for maintenance of productive forest, 93 CHF/ha for protective forest and 143 CHF/ha for forests with the leisure/nature function. Finally median marginal costs of public-service functions are estimated as follows: 116 CHF/ha for maintenance of productive forest, 93 CHF/ha for protective forest and 143 CHF/ha for forests with the leisure/nature function.

5. Conclusion

The results obtained are more or less consistent across the different empirical approaches. For the Swiss forest sector one might precisely expect important variations as the Swiss territory shows large variations of topographical and environmental conditions on very short distances. Those conditions might predetermine the decisions and behaviour of the firms. In general, the management of the forest and the production of wood depend on a great number of factors, some under the close control of the firms, such as the choices of inputs or production techniques, but a great number of factors are exogenous to the firm. These factors impose various constraints, drawn from societal, technical, environmental, political and other conditions. Examples of the complexities faced by forestry firms are given below while reporting and commenting some of the results obtained on technical efficiency, the potential of economies of scale and the role of financial contributions. Technical efficiency might be enhanced by using appropriate management techniques, economies of scale can be reached through collaborations or mergers, and financial contributions can be used to incite certain behaviour.

Technical efficiency: The results suggest a priori a rather low average level of production efficiency of the Swiss forestry firms, for total wood production, as well as by forest functions. According to the results, inputs (wood production personnel, forest vehicles, third party services, administration cost) could be reduced by at least 20 to 25% in most of the firms without reducing production. This inefficiency might be explained partly by constraints imposed on the firm, as for instance the management cannot decide spontaneously about the production according to the market circumstances (because of forest plans, or lack of infrastructure, or just because an increasing demand for forest public services). The firm might also pursue, voluntarily or not, non-economic objectives such as stability of employment.

The situations of the firms are indeed very heterogonous. The benchmark analysis of the efficient and relatively inefficient firms with respect to different characteristics of the forestry firms show that, for instance, efficient firms tend generally to fulfil less protection function, or to be located in the Mittelland rather than in the Alps. The location of the firms seems to be a strong determinant of the behaviour and the results of the firm, as the typological analysis of the FVA (Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg)[16] also suggests. Topographic, environmental and climatic factors which influence the structure and the quality of the forest and wood are to some extent correlated. In addition, low accessibility for instance increases costs and indeed the forestry firms in the Alps are more costly than in other regions. Different (forestry) regions deserve different policies, which is the case to some extent as the cantons in the regions have a great autonomy in organising and managing the forest.

Economies of scale: The results regarding the degree of economies of scale are overall consistent across the various empirical approaches. The “optimal” size of economic production for a typical firm, i.e., the level of production which is efficient and minimises costs, is about 5’000 m3, and in terms of forest surfaces about 1’000 ha. The required scale for a good performance in the protection and leisure functions are smaller and even less than 1’000 m3 for the nature and

[16] Nagel, Ph., Hercher, W. & Hartebrodt, Ch., Typologisierung des Forst-Testbetriebsnetzes der Schweiz, Abschlussbericht 31.07.2012.

landscape functions. Also, the threshold varies from one region to another. By definition, these figures are close to the means for wood production and forest areas. On average the firms included in the dataset exploit all the economies related to scale. Still there exist a large minority of smaller firms which might benefit most from an increase of size, by cooperation, or mergers. Public policy incentives may not be sufficient to overcome transaction costs and individual strategic considerations of the public forest owners, also because the financial pressure in case of the appearance of financial losses in small forestry firms is not severe for local authorities or forest owners.

Financial contributions: Theoretically, financial contributions by government may contribute to inefficiencies, as they also ease the market pressure. Not all forestry firms are profit seeking, and financial losses are often relatively small compared the total budget of local authorities. The effect of the subsidies depends on their design and the conditions at which they are attributed (lump sum, proportional to cost, project oriented subsidies, etc.). Empirically, it is then difficult to know in which direction the causation goes. For instance, the share of public contributions in revenues might be higher in firms which have higher costs. In this case, a positive correlation between subsidies and costs does not necessarily imply that the subsidies have a negative effect on efficiency. The non-parametric approach shows that efficient firms tend generally to receive less financial support (in percentage of revenue). On the other hand, in the case of the economic function only, financial contributions seem to exert a positive effect on technical efficiency. Contribution to financing protective projects or promoting the provision of public services of the forest might indeed enhance indirectly the efficiency of wood production.

On the cost side, the estimations using the TBN data show that public contributions exert a negative and important impact. This empirical evidence does not necessarily imply general policy conclusions. It might be the case that the relatively cost-efficient companies have relatively low public contributions because they do not need such assistance. Unfortunately, given the available data, it is difficult to identify the extent of causality effect in each case. In contrast, the impact of the contributions (per cent of subsidies over revenues), by using the forestry statistics, is throughout all functions significantly positive. Unfortunately, given the available data, it is difficult to identify the extent of the causality effect in each case.

Forest functions: When analysing the efficiency by forest function it appears that wood production in protective forests is generally the least efficient. This can be explained by the fact that wood production is by definition not the primary objective in protective forests. First, the growth of trees and forest as well as the production levels are generally low. Second, specific regulations (on security, e.g.) and inputs are costly (harvest, transport, road maintenance). Nothing can be inferred from these results on the efficiency of the protection against natural hazards, such as landslides, floods or avalanches.

On the other side, wood production in economic forests seems to be relatively less efficient when compared to leisure or nature and landscape forests. For the productive forest area, efficient firms, when compared to non-efficient firms, generally have a smaller productive forest area in protective forests but a larger one in nature and landscape forests. Technical efficient firms in wood production mainly appear in the Mittelland, where productive forest dominates. On the contrary, the percentage of efficient firms from the Alps is understandably the smallest.

Forest functions may interact, e.g., it could be that (cost-) efficient operations in the economic production lead also to efficiency and lower cost in the protection function. Some results suggest indeed that there are certain synergies in the form of cost-complementarity between public service functions and timber production. This means that with the “right” mix of economic and protective forest areas, both functions can be performed relatively efficiently to the advantage of the owners. However, the individual firm has scarcely any possibility to change the function of the different forest areas. Besides eventually benefitting from economies of scales, cost-complementary between functions would be an additional rational for merger and fusion of firms and forest areas, or at least for close or closer collaboration. Instead, outsourcing has become increasingly popular as a mean to reduce costs, but also for a better management of own resources. About half of the forestry firms in the sample outsource more than a quarter of their activities (measured in costs) and about 10 per cent outsource more than half. Clearly, the extent of outsourcing has a positive effect on cost-efficiency.

In terms of **public policy**, there are in the present state only little incentives set up by the federal government to increase production efficiency or to reduce production cost. For instance, with the introduction of the new federal equalisation system for cantons in 2008, the federal government pays, under certain conditions, a contribution of 40’000 francs per unit of cooperation or one franc per cubic meter in order to incite small forestry firms and owners to cooperate[17]. Other contributions are paid to enhance efficiency in logistics or in planning with the focus on sustainable forest management. The objective to improve the overall economic performance of wood production, despite increasing deficits and in the context of the other forest functions, is not (yet) on the agenda of the (public) owners, given the huge support of the population for preserving forests. The forest in Switzerland is growing, and there is a potential for increasing substantially the supply of wood without reducing the forest capital. Increasing the supply within an established national (or international) market may lead to more efficient operations, but there is today only a limited demand for timber products. Also, it is not possible to ignore the presence of the noneconomic functions and their possible interference with the production of wood. Definitively, more research is required on both the supply of and the demand for wood, and in general on the market for wood in order to search for arrangements which enhance efficiency.

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7. Nonparametric Analysis of Technical Efficiency in Multi-functional Forestry Firms (by Alexander Mack)

Technical appendix to the report:

Analysis of the production efficiency of the Swiss forestry firms with regard to the forest functions

Submitted to the
Federal Office for the Environment FOEN

October 2012, revised April 2013

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Abstract

This report explores the efficiency of Swiss forestry firms using data from a representative sample of 200 firms included in the Swiss Forestry Pilot Network (TBN/REP). The final sample is a balanced panel of 596 observations from 149 companies over a four-year period from 2007 to 2010. In order to determine the technical efficiency of the forestry firms, a nonparametric method (DEA) is used. An in-depth benchmark analysis allows a better understanding of stronger and weaker performers. In particular, we consider the multi-functionality of the forestry firms but also other characteristics, like differences in forest regions, owners, and financial indicators. The analysis also provides a measure of scale economies, and hence the corresponding optimal size. Second-stage regression is performed to determine the relationship between efficiency and selected variables, e.g., training expenditures, investments, and public contributions.

Introduction

Since the mid-1980s, forestry firms globally record important deficits in their core business, i.e., forest management and wood production. A scissors effect appeared between revenues and expenses, i.e., wood prices tend to decline and production costs increase (BAFU, 2011). Wood production and sales have ceased to cover the costs of the other tasks and activities of forest management entrusted to some 2600 forestry firms. The recent recovery of the wood market certainly improved the financial prospects of the sector, but, as shown by empirical studies (Açikgöz Ersoy and Mack, 2012; Schoenenberger, Mack, and von Gunten, 2009; Mack, 2009), there remains considerable room to improve the technical efficiency of Swiss forestry firms. Given the available data at that time, these studies focused on timber production neglecting the firms' public service role in maintaining Swiss forests.

Indeed, wood production is only one of several functions that are provided by forestry firms. These functions are generally divided into four main groups, i.e., the economic or productive function (supply of wood), and three largely non monetized functions, i.e., the protective function (e.g., protection from avalanches, air-pollution filters, protecting water resources), the leisure function (providing space for recreation), and the nature and landscape function (i.e., biodiversity and the protection of the flora and fauna). Thus taking into account all forest services and the firms' contribution in maintaining them allows a better understanding of the industry's performance. Additionally to these differences in functions, forestry firms are characterized by an important heterogeneity with respect to their size, location, topography, type of forests, and other environmental factors.

The analysis presented here is a prolongation of previous studies analyzing the efficiency of Swiss forestry firms while taking into account now their multifunctionality. The data consist of financial and technical information from 200 forestry firms included in the pilot network of forestry firms known as TBN/REP network. This network consists of a representative sample of firms selected among more than two thousand forestry firms operating throughout Switzerland. The available data include a detailed series of variables about the various aspects of the firms' activities. The focus is upon the firms' main activities related to the production of wood and the maintenance of forests. The ancillary activities are excluded from the analysis.

The rest of this report is organized into four sections. Section 0 describes the data and the model specification. Section 0 presents the methodology while reviewing a selection of previous studies. Section 0 discusses the results of the efficiency analysis, namely, the technical efficiency scores, the related improvement potentials, the main characteristics of the benchmarks, and the economies of scale and optimal size. In addition, second-stage regressions determine the relationship between efficiency and some selected variables, e.g., training expenditures, investments, and subsidies. Section 5 concludes the report with a discussion of the main results and suggestions for further research.

Data

The TBN/REP data available to us (extracted by the Swiss forest owners association (WVS), and made available by the Swiss federal statistical office (FSO)) is an unbalanced panel of 802 observations covering 229 firms over a four-year period (2007 to 2010), and associated to 88 variables. Most of these variables are divided into the four forest functions (economic function (WW), protection (SW), leisure (EW), nature and landscape (N&L)). The annual data consists of 200 firms (besides 2008 where 202 firms can be found) including financial and technical information about the firms. Besides some general characteristics of the firms, the data include analytical accounting information that tracks physical and/or monetary inputs and outputs mostly for the four functional categories as defined above. As Table 1 shows, data is available for 175 firms over the entire four-year period (balanced panel). For 19 firms data is available for one single year only, 22 firms occur during two years, and 13 firms appear during three years.

Table 1: Occurrence of firms over the four-year period

Year	Firms
2007	6
2008	1
2009	2
2010	10
2007-2008	11
2008-2009	3
2009-2010	8
2007 & 2009-10	1
2007-08 & 2010	1
2007-2009	6
2008-2010	5
2007-2010	229
2007-2010 (balanced panel)	175

After analyzing the data, and in the framework of the efficiency analysis (mainly for reasons of consistency, robustness, and comparison over time), we decided to focus on a sub-sample of 149 companies hence a balanced panel data of 596 observations (2007-2010). Indeed, firms without wood production were directly excluded from the analysis of efficiency related to wood production (one firm during the whole four-year period, and one firm in 2010). Moreover, firms with no personnel (hours worked) in wood production (P) and, at the same time, no use of own vehicles (V, in machine hours) in wood production were also excluded from the sample. Additionally, we checked for firms without personnel (in wood production), no use of own forest vehicles (in wood production) or zero administrative expenditures (ADM), and, at the same time, zero spending on third-party services (outsourcing) (3rdPS). Table 2 resumes the selection process leading to a balanced panel of 149 firms.

Table 2: TBN firm selection process

Year	Total number of firms	Without production	P = V = 0 (P = 3rdPS = 0) (V = 3rdPS = 0)* (ADM = 3rdPS = 0)	Remaining number of firms	Balanced Panel
2007	200	1	25	174	149
2008	202	1	24 (1)*	177	149
2009	200	1	26 (1)*	173	149
2010	200	2	22	176	149

The variables included in the efficiency analysis are listed in Table 3, which also provides a descriptive summary of the selected data. The table distinguishes among output and input variables, and also shows the variables used in second-stage regression.

Table 3: Descriptive statistics (596 observations from 149 forestry firms, 2007-2010)

Variable		Mean	Std. Dev.	Min.	Max.
	Output variables				
Q	Total annual wood production (m^3)	5065.6	3390.3	368.0	17653.0
Q^1	Production (KT501)	3716.8	3606.9	0.0 (20%)	17481.9
Q^2	Protection (KT502)	1146.4	2052.1	0.0 (57%)	14190.8
Q^3	Leisure (KT503)	117.9	544.6	-6.0 (86%)	9587.0
Q^4	Nature & landscape (KT504)	82.8	345.3	0.0 (85%)	3727.0
	Timber production by wood category (m^3)				
W^1	Cut wood	2981.4	2239.9	3.0	13349.1
W^2	Firewood	1224.3	1194.1	0.0 (4%)	7403.0
W^3	Industrial wood & other assortments	725.6	1007.1	-291.0	6783.1
A	Productive forest area (ha)	930.3	810.7	50.0	5810.0
A^1	Production	466.8	454.4	0.0 (15%)	2607.0
A^2	Protection	382.9	756.7	0.0 (53%)	5156.1
A^3	Leisure / Nature & landscape	78.7	153.6	0.0 (61%)	1425.0

R	Roads (m/ha)	79.6	74.6	0.0 (6%)	542.0
	Input variables				
P	Wood production personnel (h)	3048.0	2338.9	0.0 (.2%)	13901.0
P^1	Production	1948.6	1990.7	0.0 (20%)	11563.0
P^2	Protection	914.9	1673.6	0.0 (57%)	9550.0
P^3	Leisure	108.4	425.7	0.0 (84%)	5915.0
P^4	Nature & landscape	75.5	372.4	0.0 (82%)	4842.3
V	Total forest vehicles (mh)	2827.6	3928.6	0.0 (12%)	40236.0
V^1	Production	1408.7	2293.0	0.0 (30%)	19219.0
V^2	Protection	1246.1	2833.3	0.0 (62%)	20578.5
V^3	Leisure	106.9	598.2	0.0 (86%)	9365.0
V^4	Nature & landscape	65.9	317.0	0.0 (86%)	4002.0
3rdPS	Third-party services (CHF)	166949.8	153760.9	0.0 (.7%)	959962.0
$3rdPS^1$	Production	98641.1	125277.7	0.0 (22%)	757900.6
$3rdPS^2$	Protection	60788.9	118814.6	0.0 (57%)	716075.3
$3rdPS^3$	Leisure	4072.5	14454.5	-51.0 (76%)	202060.0
$3rdPS^4$	Nature & landscape	3402.2	12179.7	0.0 (79%)	118788.0
ADM	Administration costs (CHF)	80981.1	89093.4	1983.0	889185.5
ADM^1	Production	55345.7	78296.9	0.0 (17%)	729583.9
ADM^2	Protection	18518.7	32818.6	-106.0 (50%)	184129.0
ADM^3	Leisure	4619.2	14219.1	0.0 (53%)	159953.0
ADM^4	Nature & landscape	2483.5	6463.1	0.0 (54%)	53241.5
	Other variables				
ZUW	Total wood growth (sv)	12918.7	90137.9	0.0 (2%)	1106059.0
RR	Revenues received (CHF)	133962.1	129891.6	0.0 (2%)	857146.0
RR^1	Production	80669.4	108501.5	0.0 (23%)	729164.9
RR^2	Protection	48977.0	96708.1	0.0 (59%)	685377.9
RR^3	Leisure	2255.5	11156.3	0.0 (89%)	176322.0
RR^4	Nature & landscape	2026.2	9048.7	0.0 (89%)	106689.0
EDU	Training (CHF)	12622.1	20332.5	-1.0 (14%)	246512.0
INV	Investments (CHF)	92198.4	256693.9	0.0 (42%)	3728283.7

SUB	Contributions (CHF)	160552.8	171785.3	0.0 (1%)	1061438.0
SUB¹	Production	57570.2	68324.9	0.0 (27%)	708613.1
SUB²	Protection	89229.3	170937.7	0.0 (57%)	1022693.0
SUB³	Leisure	6465.4	22631.9	-9968.0 (82%)	219057.0
SUB⁴	Nature & landscape	7287.8	19222.7	0.0 (70%)	196818.0

Model Specification

The method used here to analyze the (technical) efficiency of the forestry firms is a non-parametric method (i.e., no hypothesis is done concerning the functional form of the production technology or the distribution of the random residuals) called Data Envelopment Analysis (DEA). Developed by Charnes, Cooper and Rhodes (1978), and derived from the work of Farrell (1957), it generalizes the concept of efficiency for multiple inputs and outputs to construct a mathematical optimization program, whose solution provides a measure of efficiency, relative to the frontier. The units considered here, i.e., the forestry firms, take, by assumption, autonomous decisions, particularly regarding the production and the factors used. They transform, given the existing technology, inputs (in particular labor and capital) into outputs (wood).

In other words, DEA measures the efficiency of a decision making unit (DMU) by calculating the relative difference between the point representing the value of observed inputs and outputs, and a hypothetical point on the frontier of that same production. The method is then used to identify best practices with respect to all observations, that is to say the production frontier, and thus to measure the efficiency degree (score) of each unit. To account, then, for the effect of the environment likely to influence the performance of the forestry firms, the efficiency scores obtained from the DEA analysis are regressed, in the second stage, on environmental variables, i.e., (exogenous) factors that are not or only indirectly under the control of a firm.

The efficiency degree (E) is determined by maximizing the ratio of the sum of weighted outputs with respect to the sum of weighted inputs for each decision unit j. No efficiency score for any DMU is larger than unity (maximum efficiency). Except the case of deliberately choosing an individual weighting, the weights are determined by the optimization program. The value of the ratio, calculated for all DMUs of the considered population, for one time period or a series of time periods, is necessarily comprised between 0 and 1. The DMUs on the frontier have by definition an efficiency equal to 1; the inefficient units have an efficiency score inferior to unity ($E < 1$). Thus, for each DMU j (Badillo and Paradi, 1999), the efficiency score is calculated in the following way:

E_j = sum of weighted outputs / sum of weighted inputs, where:

$$E_j = \frac{w_1\ y_{1j} + w_2\ y_{2j} + \cdots}{v_1\ x_{1j} + v_2\ x_{2j} + \cdots} = \frac{\sum_r w_r\ y_{rj}}{\sum_i v_i\ x_{ij}}$$

where w_r = weighting attributed to output r, y_{rj} = sum of output r of unit j;
v_i = weighting attributed to input i, x_{ij} = sum of input i for unit j

The issue is about finding a common set of weights to determine the relative efficiency. Charnes, Cooper and Rhodes (1978) suppose that DMUs can evaluate differently their inputs and outputs, hence choosing different weights. Consequently, each DMU is free to adopt a set of weights which allows to be shown in the most favourable way compared to the other units (Emrouznejad, 1995-2012). To respect this choice, the DEA method calculates separate weights for each unit while keeping those that provide the best result for the unit considered. It should be noted that different weights can change the efficiency ratio.

Under these conditions the efficiency of one unit (j = 0) can be obtained as the solution of the following problem: Maximize Ej under the constraint Ej ≤ 1 for all units of the considered population. To avoid ignoring any input or output all weighting coefficients are positive. In other words:

$$MaxE_0(w,v) = \frac{\sum_r w_r\ y_{r0}}{\sum_i v_i\ x_{i0}}$$

s.t. $\frac{\sum_r w_r\ y_{rj}}{\sum_i v_i\ x_{ij}} \leq 1$ for each unit *j*.

$w_r,\ v_i \geq \varepsilon$ with $\varepsilon > 0$

To solve this maximization problem it is first necessary to linearize this model before applying to it linear programming methods (Banker *et al.*, 1984; Emrouznejad, 1995-2012). Thus, the DEA method allows identifying an efficient set which can serve as a reference set for all inefficient units. The reference set corresponds to a group of units having the best practice. The efficient DMUs have similar inputs and outputs when compared to the inefficient units, hence serving as potential reference partners.

To estimate the wood production frontier of the forestry firms an input oriented approach is used (i.e., the same output is produced with less input). The choice to minimize the volume of inputs is due to budget constraints which concern most of the public forestry firms. Until now we considered the assumption of constant returns to scale (CRS) as in the initial model of Charnes, Cooper and Rhodes (1978). Nevertheless, this hypothesis is only suitable if all DMUs operate at an optimal scale. For example, a market under imperfect competition or constraints at the financial level might be some of the reasons for a firm to not produce at an optimal scale. Banker, Charnes and Cooper (1984) have proposed an extension to the DEA model with constant returns to scale to allow for variable returns to scale (VRS). Indeed, the use of the CRS specification in a situation where not all firms operate at an optimal scale results in a measure of efficiency biased by scale efficiencies. In other words, the use of the VRS specification allows determining the technical efficiency without scale effects. The problem of linear programming under the CRS assumption can be easily adapted to the VRS case by introducing an additional constraint of convexity (Jacobs *et al.*, 2006, p. 101).

Besides traditional input factors (i.e., labor and capital) used in the process of wood production, so-called environmental factors probably will influence the efficiency of a firm. These inputs (e.g., climate factors, topographic factors, wood growth, contributions) are not traditional inputs (or outputs), and are supposed to be not (directly) under the control of the firm's manager. Different approaches exist in the framework of the DEA method allowing the integration of such environmental factors (Fried *et al.*, 2002). The typical two-step approach follows a DEA analysis in the first step based on ordinary inputs and outputs, followed by a regression analysis in the second step (several studies use ordinary least squares (OLS), others a Tobit model) which tries to explain the variation of the efficiency scores obtained in the first step by a vector of observable environmental variables. Timmer (1971) was the first to propose this approach, and several studies improved it later on by using regression models for limited dependent variables as the efficiency scores are bound by 0 and 1, and often reach their upper limit. Lissitsa *et al.* (2005) avoid the problem of censured variables by using the super-efficiency scores that are not bound by 1, hence making it possible to apply the OLS method to these data (as done in this report). Indeed, Andersen and Petersen (1993) propose a model that allows classifying firms that have reached efficiency scores of 100% by one of the standard DEA models. Mathematically, the super-efficiency model is identical to the basic DEA models except that the unit under evaluation is not included in the reference set. The super-efficiency score of an inefficient firm will not be different from the standard efficiency score as an inefficient firm cannot be a reference firm for itself. On the other side, an efficient firm could obtain a super-efficiency score exceeding 1. A high super-efficiency score indicates that a firm is high above its peers, and thus should be highly ranked.

The basic model (model 1) for determining the technical efficiency of the firms is an input-oriented model containing one output (total annual wood production in m^3) and four inputs: wood production personnel (h), total forest vehicles (mh), third-party services (CHF), and administration costs related to wood production (CHF). Model 1 (M1) has been tested for the total wood production, i.e., all forest functions taken together, but also for each forest function individually. As the firms are relatively heterogeneous in terms of size, we assume variable returns to scale (VRS).

Table 4: Variable definition and model

Variables (O = Output; I = Input)		
M1	**M2**	**Unit**
Total annual wood production (O)		m3
	Cut wood (O)	m3
	Firewood (O)	m3
	Industrial wood & other assortments (O)	m3
	Productive forest area (KT 501) (O)	ha
	Productive forest area (KT 502) (O)	ha
	Productive forest area (KT 503&504) (O)	ha
	Roads (O)	m/ha
Wood production personnel (I)	Wood production personnel (I)	Hours
Total forest vehicles (I)	Total forest vehicles (I)	Machine hours
Third-party services (I)	Third-party services (I)	Swiss francs
Administration costs for wood production (I)		Swiss francs

Model 2 (M2) is set up for a better comparison with the results found in the framework of the econometric analysis of costs in multi-output forestry firms. M2 consists of seven outputs (cut wood, firewood, industrial wood and other assortments; productive forest area for production, protection, leisure / nature and landscape; roads) and three inputs (working hours, i.e., wood

production personnel; machine hours, i.e., total forest vehicles; third-party services). Table 4 above resumes the two models analyzed and the variables included in the efficiency analysis.

Results

Table 5 shows the results of the (technical) efficiency analysis in case of model 1 for total wood production and all forest functions taken together. The results indicate an average efficiency of 58.9% in 2007, decreasing to less than 53% in 2009. A slight upturn can be observed for 2010 (53.6%). The relatively low efficiency scores indicate an important potential for increasing the efficiency of Swiss public forestry firms. This result is confirmed by some very low minimum scores that can be observed during the whole period analyzed. The number of firms with efficiency scores equal to or higher than 50% is indicated in the before-last column, and the last column shows the number of efficient firms (100%) serving as benchmarks.

Table 5: Efficiency scores (M1, IO, VRS)

Year	*N* = 596	Mean	Median	S.D.	Min.	Max.	≥50%	Efficient
2007	n=149	58.9%	51.0%	29.9%	7.2%	100%	79	36
2008	n=149	54.9%	46.8%	27.9%	11.1%	100%	71	30
2009	n=149	52.5%	46.2%	26.8%	10.6%	100%	64	24
2010	n=149	53.6%	47.1%	27.2%	8.6%	100%	68	22

Figure 1 illustrates the distribution of the efficiency scores for all forestry firms over the four-year period for model 1. The x-axis represents the efficiency scores in percentage, and the y-axis shows the number of firms.

Figure 1: Distribution of scores (M1)

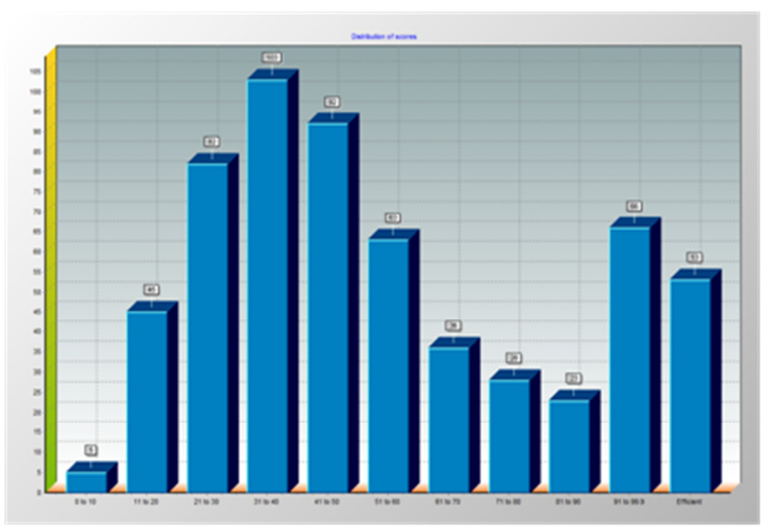


Table 6 lists a summary of potential improvements, i.e., the average amount of input reduction for reaching full technical efficiency. Overall it seems that in average, and when comparing to the benchmarks, inputs could be reduced by around one-quarter while keeping the output constant.

Table 6: Improvement summary

Wood production	+1.37%
Labor (wood production personnel)	-23.54%
Capital (total forest vehicles)	-28.57%
Third-party services	-23.91%
Administration costs for wood production	-22.61%

Table 7 shows the results of the (technical) efficiency analysis for wood production in case of model 1 by forest function.

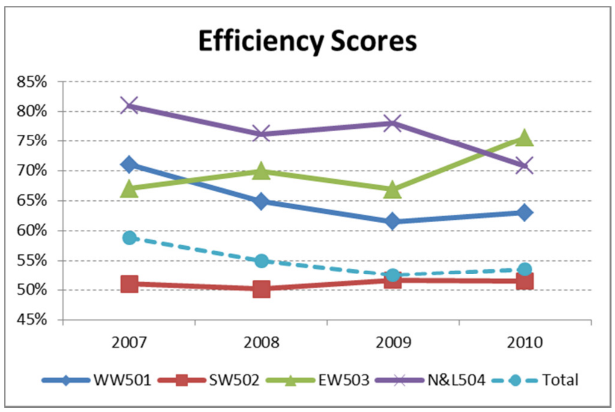
Table 7: Efficiency scores by forest function (M1, IO, VRS)

WW501	***N* = 505**	**Mean**	**Median**	**S.D.**	**Min.**	**Max.**	**≥50%**	**Efficient**
2007	n = 127	71.1%	71.9%	26.3%	23.3%	100%	91	34
2008	n = 126	64.9%	60.0%	25.9%	7.3%	100%	79	23
2009	n = 126	61.5%	55.8%	25.7%	10.6%	100%	74	21
2010	n = 126	63.0%	61.2%	25.1%	10.9%	100%	77	19
SW502	***N* = 281**							
2007	n=68	51.0%	36.5%	35.2%	1.4%	100%	26	20
2008	n=70	50.1%	39.1%	33.4%	0.3%	100%	27	19
2009	n=72	51.7%	35.3%	34.8%	3.6%	100%	27	21
2010	n=71	51.5%	40.5%	35.6%	1.0%	100%	28	22
EW503	**N = 168**							
2007	n=43	67.0%	87.0%	37.2%	0.6%	100%	27	20
2008	n=42	70.0%	100.0%	38.9%	0.1%	100%	26	23
2009	n=41	66.9%	100.0%	40.1%	0.6%	100%	25	22
2010	n=42	75.6%	100.0%	35.5%	0.7%	100%	31	24
N&L504	***N* = 196**							
2007	n=52	81.0%	100.0%	35.5%	0.3%	100%	41	39
2008	n=51	76.3%	100.0%	40.7%	1.3%	100%	38	37
2009	n=47	78.0%	100.0%	38.5%	0.9%	100%	35	35
2010	n=46	70.8%	100.0%	42.0%	2.3%	100%	31	30

In case of the economic forest (WW501/production) the efficiency scores decrease from around 71% in 2007 to less than 62% in 2009, before slightly increasing again. As one could almost expect, the efficiency scores are relatively low in the case of protective forests (SW502/protection) fluctuating around 51% over the four-year period. Note that in case of protective forests the largest improvement potential in terms of input factors used seems to be in administrative costs which should be reduced by almost one half (-48.14% in average) for reaching full efficiency. The efficiency of wood production in leisure forests (EW503) is between 67% and 70% during 2007 and 2009, and increases to more than 75% in 2010. Finally, even though the technical efficiency in wood production in nature and landscape forests (N&L504) starts from a relatively high level in 2007 (81%), it decreases over the four-year period to reach less than 71% in 2010. Nevertheless, the overall small amount of wood produced in this type of forests has to be underlined.

Figure 2 resumes graphically the average technical efficiency scores for wood production when taking all forest functions together (total) and by forest function.

Figure 2: Technical efficiency by forest function (M1, IO, VRS)



To better understand the relative efficiency or inefficiency of the forestry firms, a closer look on the benchmarks is proposed in what follows. Based on a certain number of firm characteristics, we therefore compare the technically efficient firms (benchmarks, efficiency = 100%) with the non-efficient ones (efficiency < 100%). To refine the analysis, we distinguish three different categories of non-efficient firms, i.e., firms with technical efficiency scores smaller or equal than 75%, smaller than 50%, and inferior to 25%. Moreover, we indicate the mean values of the different characteristics for the whole panel, and we also indicate the variation for those values obtained for the benchmarks compared to the values of the panel (Δ (Panel)). Like this we can quickly see if efficient firms receive in average more or less contributions, for example, than all firms taken together (panel).

Table 8 shows the results of the benchmark analysis for a selection of variables characterizing the firms. For example, it appears that efficient firms use in average less working hours and less machine hours in the wood production process than non-efficient firms, and have lower administrative costs. Moreover, efficient firms receive generally less contributions than non-efficient firms; the same observation can be done when analyzing the percentage of contributions as part of total revenues in wood production. Finally, we observe that technically efficient firms are generally less diversified than non-efficient firms, i.e., their turnover from wood production is more important.

Table 8: Benchmark analysis (technical efficiency)

M1 IO VRS (mean values, 2007-2010)	Panel	Benchmarks (100%)	Δ (Panel)	Efficiency ≥75%	Efficiency <50%	Efficiency <25%
Wood production (m3)*	5065.6	4822.6	-4.8%	5355.6	4845.2	4619.3
Labor (h)	3048.0	2721.8	-10.7%	2920.1	3091.2	3316.2
Capital (Mh)	2827.6	2572	-9.0%	2444.8	3018.9	3300.8
Administration costs (CHF)	80981.1	70124.9	-13.4%	77271.7	84774.7	103602.4
3rd party services (CHF)	166949.8	162554.3	-2.6%	166108.8	166822.6	155869.0
Contributions (CHF)	160552.8	136684.7	-14.9%	149746.3	167014.0	170229.2
Contributions (% of TR WP)	27.7%	24.8%	-10.4%	25.3%	29.9%	32.5%
Investments (CHF)	92198.4	71499.4	-22.5%	74646.6	98909.3	104543.4
Investment revenues (CHF)	41993.1	40697.1	-3.1%	42683.3	41209.7	26958.1
Total costs/total revenues	1.08	1.11	2.9%	1.07	1.11	1.26
Diversification (turnover wood production / total TO)	61.10%	64.70%	5.9%	62.40%	56.68%	54.02%

*TBN/REP average: 4648.8 m^3

Table 9 illustrates the results (mean values for the period analyzed) of the benchmark analysis with respect to the productive forest area in total and by forest function. It can be shown that, in average, efficient firms, compared to non-efficient firms, have less productive area in protective forests, but generally more in nature and landscape forests.

Table 9: Benchmark analysis – Productive forest area

Productive forest area (ha)	Panel	Benchmarks (100%)	Δ (Panel)	Benchmarks ≥75%	Efficiency <50%	Efficiency <25%
Total*	930.3	882.3	-5.2%	924.9	946.4	926.5
501 (economic function)	466.8	415.6	-11.0%	466.8	455.7	413.5
502 (protection)	382.9	356.2	-7.0%	366.8	413.4	441.1
503 (leisure)	28	25.3	-9.8%	23.2	33.7	26.7
504 (nature & landscape)	50.7	78.3	54.4%	64.2	42.5	41.0

*TBN/REP average: 946.5 ha

Table 10 shows the percentage of firms dealing with the different forest functions during the period analyzed (2007-2010, mean values). It appears that efficient firms generally fulfill less protective functions than less efficient firms; on the other side, efficient firms fulfil more nature and landscape functions (see also above, productive forest area).

Table 10: Benchmark analysis – Firms by forest function

% of all firms	Panel	Benchmarks (100%)	Δ (Panel)	Efficiency ≥75%	Efficiency <50%	Efficiency <25%
501 (economic function)	84.7%	85.2%	0.5%	88.4%	81.8%	77.6%
502 (protection)	47.1%	48.5%	2.8%	45.1%	50.3%	53.9%
503 (leisure)	28.2%	32.6%	15.5%	26.8%	29.9%	27.6%
504 (nature & landscape)	32.9%	43.2%	31.5%	36.6%	33.1%	34.2%

TBN/REP average: 501: 83%, 502: 50%, 503: 27%, 504: 31%

Table 11 shows the percentage distribution of firms by forest region. It appears that technically efficient firms are generally located in the Mittelland and less in the Alps and Prealps regions.

Table 11: Benchmark analysis – Firms by forest region

Forest region	Panel	Benchmarks (100%)	Δ (Panel)	Efficiency ≥75%	Efficiency <50%	Efficiency <25%
Jura	26.5%	27.7%	4.4%	25.0%	27.1%	22.4%
Mittelland	33.4%	37.5%	12.3%	37.2%	30.6%	34.2%
Prealps	17.1%	12.5%	-27.0%	17.7%	17.5%	15.8%
Alps	22.5%	21.4%	-4.7%	19.5%	24.2%	25.0%
(Alpine south side)	0.5%	0.9%	77.4%	0.6%	0.64%	2.6%

TBN/REP average: JU: 27%, ML: 32%, PA: 17%, A: 24%, ASS: 1%

Table 12 illustrates the percentage distribution of firms by some of the main owners' categories. The results show that firms of political communes as well as firms belonging to cooperatives have (in average, 2007-2010) higher efficiency scores. On the other side, less efficient firms belong more often to Bürgergemeinden.

Table 12: Benchmark analysis – Firms by owners

Owners	Panel	Benchmarks (100%)	Δ (Panel)	Efficiency ≥75%	Efficiency <50%	Efficiency <25%
(State)	2.7%	5.4%	99.6%	4.3%	2.9%	2.6%
Political commune	15.8%	21.4%	35.9%	17.1%	14.0%	10.5%
Bürgergemeinde	29.2%	18.8%	-35.8%	22.0%	30.9%	27.6%
Cooperative	8.6%	12.5%	46.1%	14.0%	6.4%	2.6%
Political commune & Bürgerg.	16.8%	17.0%	1.1%	17.1%	15.9%	23.7%
Other	27.0%	25.0%	-7.5%	25.6%	29.9%	32.9%

TBN/REP average: St.: 5%, PC: 19%, B: 27%, Coop: 8%, PC&B: 18%, other: 23%

Table 13 illustrates the production of wood by assortments. For example, the results show that efficient firms generally sell more standing timber and produce more round wood (total).

Table 13: Benchmark analysis – Wood production by assortment

m3	Panel	Benchmarks (100%)	Δ (Panel)	Efficiency ≥75%	Efficiency <50%	Efficiency <25%
Production of cut wood	4744.8	4329.1	-8.8%	4816.6	4623.8	4331.4
Sales of cut wood	4697.9	4366.1	-7.1%	4799.4	4574.6	4288.4
Sales of standing timber	301.5	538.6	78.6%	534.4	220.3	283.5
Total round wood	2969.1	3102.5	4.5%	3300.4	2769.0	2584.1
Deciduous round wood	365.6	281.8	-22.9%	318.9	369.1	395.4
Total industrial wood	687.7	510.3	-25.8%	639.5	674.2	560.9
Deciduous industrial wood	324.9	181.2	-44.2%	257.1	331.1	287.8
Total firewood	1224.8	1033.3	-15.6%	1173.9	1254.9	1321.4
Deciduous firewood	987.5	771.9	-21.8%	888.3	1030.8	1071.2
Other assortments	34.5	35.9	4.3%	45.3	32.9	11.93

Table shows the link between efficiency and diversification, i.e., turnover of wood production divided by total turnover. The results show that, in average and over the whole period analyzed, poorly diversified firms are more efficient than more diversified firms (see also above). Moreover, it appears that weakly diversified firms (TO WP/TTO ≥ 50% and < 80%) have, in average, lower deficits in wood production and for the total firm than strongly diversified firms (TO WP/TTO ≥ 30% and < 50%).

Table 14: Efficiency and diversification

TO WP/TTO	Number of firms	% of all firms	Average efficiency	Average profit WP	CHF/productive ha	CHF/m3	Total average profit
≥80%	105	17.6%	61.4%	CHF -65'529	-69.2	-11.3	CHF -102'710
≥50% and <80%	322	54.0%	54.8%	CHF -21'189	-21.4	-3.7	CHF -90'476
≥30% and <50%	129	21.6%	51.6%	CHF -79'451	-90.7	-21.6	CHF -228'734
<30%	40	6.7%	51.0%	CHF -70'117	-121.7	-36.9	CHF -140'375

Table 15 shows the results of the returns to scale analysis for model 1 by indicating the percentage of firms concerned by increasing or decreasing returns to scale for the whole period analyzed (2007-2010), and for all forest functions taken together (total) as well as by forest function. Indeed, as mentioned above, the DEA technique also allows identifying scale economies. The results show that for all forest functions combined, almost three quarters of the firms have passed the “optimal size” (in terms of wood production). The same reasoning applies when looking at the economic and protection functions. E.g., producing (in average) 1806 m^3 of wood in an economic forest seems to be not sufficient (for reaching an optimal size), on the other side producing 4979 m^3 seems to be too much. Finally, firms seem to be “too small” in average when looking at leisure but also nature & landscape functions. The last two columns of the table indicate the average productive forest area for firms with increasing or decreasing returns to scale. For example, all forest functions taken together (total), it seems that the optimal size (in terms of productive forest area) lies in between 615 ha and 1043 ha.

Table 15: Returns to scale (M1)

	Increasing returns to scale (IRS)	Decreasing returns to scale (DRS)	Average production (m3) IRS	Average production (m3) DRS	Average productive forest area (ha) IRS	Average productive forest area (ha) DRS
Total	26.3%	73.7%	2720.2	5903.3	615.2	1042.7
Min / Max			*368 / 9658*	*824 / 17653*	*50 / 2607*	*139 / 5810*
501 (economic function)	20.0%	80.0%	1806.2	4979.2	385.3	592.9
Min / Max			*0 / 8442*	*25 / 17482*	*5 / 2607*	*9 / 2607*
502 (protection)	24.6%	75.4%	808.3	2935.0	311.2	975.1
Min / Max			*0 / 5226*	*28 / 14191*	*1 / 1914*	*1 / 5156*
503 (leisure)	73.2%	26.8%	58.7	1449.7	69.1	192.3
504 (nature & landscape)	78.6%	21.4%	100.0	717.6	142.3	209.5

In what follows, we analyze the relation which exists between efficiency and some selected financial variables, i.e., firms’ wood production revenues, wood production profits, total investments, and wood production contributions. The efficiency corresponds to the efficiency scores obtained for all firms over the whole period analyzed (2007-2010) under model 1.

Figure 3 illustrates the almost non-existent link between efficiency and firm revenues. I.e., having high or low revenues does not seem to have any influence on the technical efficiency of forestry firms and vice versa.

Figure 3: Efficiency vs. revenues (2007-2010)

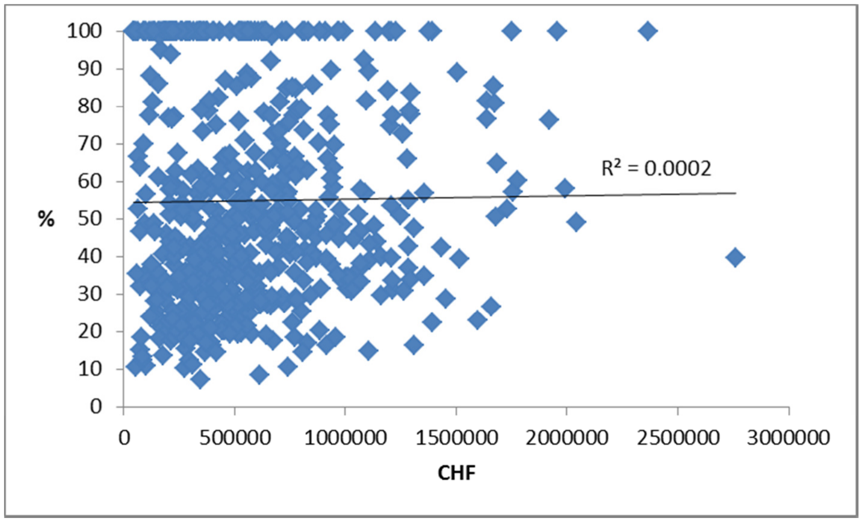


Figure 4 shows the relation between efficiency and the firms' profits. Even though the link appears to be weak it nevertheless seems to be positive. In other words, higher profits seem to be favorable for higher efficiency and/or vice versa.

Figure 4: Efficiency vs. profits (2007-2010)

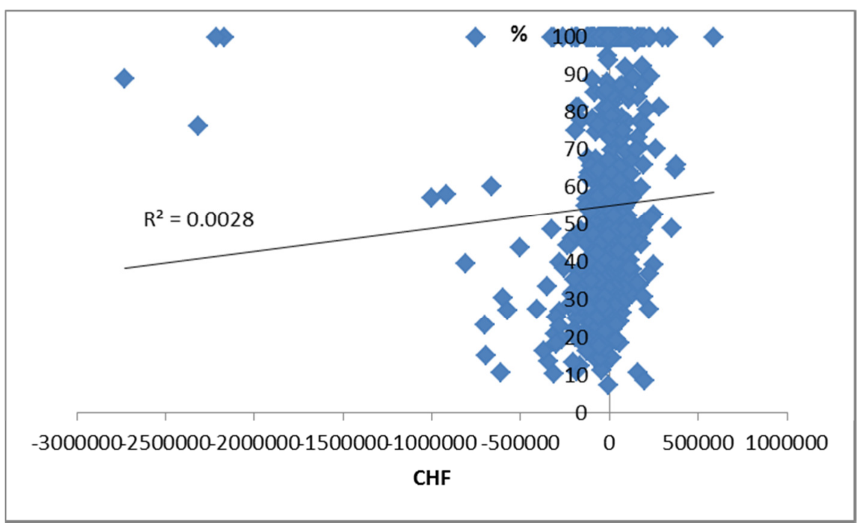


Figure 5 indicates the relation between efficiency and total investments of forestry firms. Even though the link appears to be weak again, there seems to be this time a negative relation between efficiency and investments, i.e., higher investments do not lead to higher efficiency and vice versa.

Figure 5: Efficiency vs. investments (2007-2010)

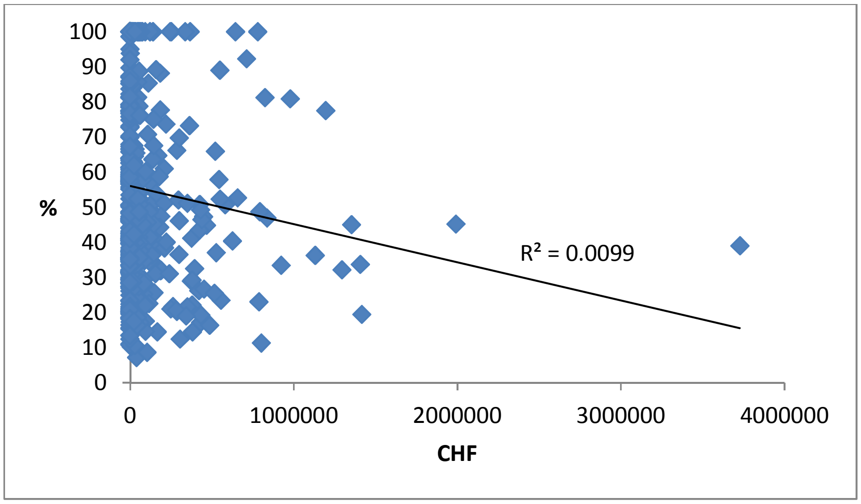
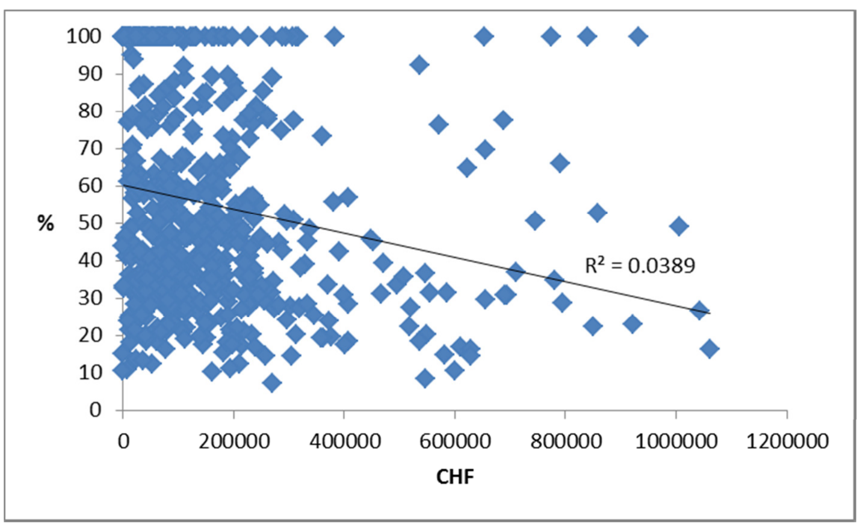


Figure 6 illustrates the relation between efficiency and wood production contributions. Even though the relation appears to be weak, it seems to be negative. In other words, higher efficiency means fewer contributions or: higher contributions lead to lower efficiency?

Figure 6: Efficiency vs. contributions (2007-2010)



To allow for a better comparison with the results found in the framework of the econometric analysis of costs in multi-output forestry firms a second model (M2) was set up. M2 consists of seven outputs and three inputs (see Table 4). The results of the DEA efficiency analysis are presented in Table 16. It basically appears that, compared to model 1 (M1), the efficiency scores are now higher in average. This is not surprising in the sense that the discriminating power of the model decreased as the number of variables used in this model is now larger. The number of firms with efficiency scores larger or equal to 50% also increased as well as the number of efficient firms.

Table 16: Efficiency scores (M2, IO, VRS)

Year	*N* = 596	Mean	Median	S.D.	Min.	Max.	≥50%	Efficient
2007	n=149	70.3%	74.7%	27.7%	18.2%	100%	104	50
2008	n=149	65.5%	64.2%	28.2%	9.9%	100%	93	41
2009	n=149	65.8%	61.3%	29.1%	12.3%	100%	91	49
2010	n=149	66.7%	67.2%	28.8%	10.8%	100%	97	44

Figure 7 illustrates the distribution of the efficiency scores for all forestry firms over the four-year period for model 2. Again, the x-axis represents the efficiency scores in percentage, and the y-axis shows the number of firms.

Figure 7: Distribution of scores (M2)

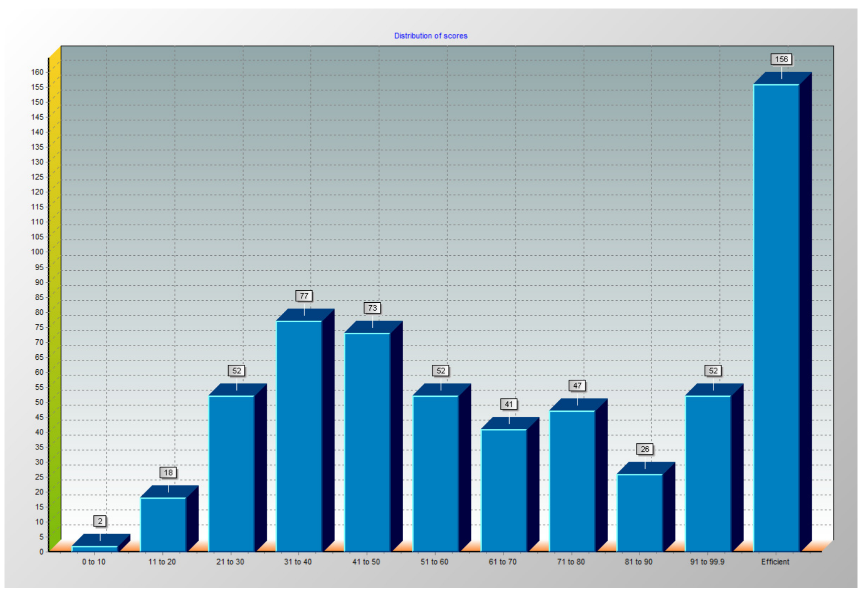


Table 17 shows the results of the returns to scale analysis for model 2 by indicating the percentage of firms concerned by increasing or decreasing returns to scale for the whole period analyzed (2007-2010), and for all forest functions taken together (total). The results show that for all forest functions combined, approximately three quarters of the firms have passed the “optimal size” (in terms of wood production). Thus, producing (in average) 2262 m^3 of wood seems to be not sufficient (for reaching an optimal size), on the other side producing 5957 m^3 seems to be a too large quantity. The last two columns of the table indicate the average productive forest area for firms with increasing or decreasing returns to scale. All forest functions taken together (total), it seems that the optimal size (in terms of productive forest area) lies in between 402 ha and 1099 ha. Note that these results are comparable with the results found in the framework of model 1.

Table 17: Returns to scale (M2)

	Increasing returns to scale (IRS)	Decreasing returns to scale (DRS)	Average production (m3) IRS	Average production (m3) DRS	Average productive forest area (ha) IRS	Average productive forest area (ha) DRS
Total	24.2%	75.8%	2261.8	5956.8	401.8	1098.8

Finally, to determine the influence of some selected variables on the efficiency of Swiss forestry firms, a second-stage regression is performed. These variables are total wood growth, the revenues received of a firm for work done for third parties, training expenditures, total investments, and contributions received (for wood production). See Table 18.

Table 18: Additional explanatory variables

Variables	Unit
Total wood growth	(Silven)
Revenues received	Swiss francs
Training	Swiss francs
Investments	Swiss francs
Contributions	Swiss francs

The results of the second-stage regression for model 1 and model 2 are presented in what follows. As illustrated by Table 19, and when looking at all forest functions together (overall M1), the revenues received by a firm for work done for third parties, training expenditures, and total investments, have all a significant negative impact on efficiency. At the same time, wood growth and contributions received (for wood production) have no significant influence on efficiency. When checking individually by forest function, i.e. analyzing specifically the effect of revenues received and contributions by forest function (note: for the other variables used for the regression analysis, a distinction by forest function is not available), the results stay globally coherent besides one exception which is for contributions received in economic forests. Indeed, it seems that for this forest function, contributions have a positive effect on efficiency. Finally, it has to be underlined that the explanatory power of the regressions is very low (e.g., only 12% of the variation of the efficiency scores can be explained by the variables used in case of the overall model), in particular for forest functions 503 and 504.

Table 19: Second-stage regression (M1)

Dependent Variable: ln (Eff. Score)
Method: Least Squares
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Overall M1 2007-2010	501WW 2007-2010	502SW 2007-2010	503EW 2007-2010	504N&L 2007-2010
Const.	**4.876**	**3.868**	**4.103**	**4.012**	**3.955**
	*(17.325)****	*(28.331)****	*(30.767)****	*(29.566)****	*(28.590)****
ln (Wood Growth)	**0.008**	**-0.005**	**-0.002**	**-0.004**	**0.001**
	(0.526)	*(-0.333)*	*(-0.108)*	*(-0.259)*	*(0.089)*
ln (Rev. Received)[1]	**-0.061**	**-0.009**	**-0.032**	**-0.018**	**-0.002**
	*(-3.217)****	*(-0.876)*	*(-2.905)****	*(-2.070)***	*(-0.247)*
ln (Training)	**-0.021**	**-0.030**	**-0.030**	**-0.023**	**-0.025**
	*(-3.029)****	*(-3.747)****	*(-4.206)****	*(-3.102)****	*(-3.403)****
ln (Investments)	**-0.015**	**-0.015**	**-0.013**	**-0.020**	**-0.020**
	*(-3.653)****	*(-3.392)****	*(-3.001)****	*(-4.480)****	*(-4.369)****
ln (Contributions)[1]	**-0.031**	**0.030**	**0.005**	**-0.004**	**0.003**
	(-1.277)	*(3.010)****	*(0.435)*	*(-0.722)*	*(0.554)*
Adjusted R^2	0.12	0.09	0.12	0.07	0.06
DW	1.87	1.98	1.97	1.97	1.99
Observations	596	596	596	596	596

In brackets, t-statistics.
*** significant at 1%, ** significant at 5%, * significant à 10%
[1] Depending on the forest function.

Table 20: Second-stage regression (M2)

Dependent Variable: ln (Eff. Score)
Method: Least Squares
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Overall M2 2007-2010	501WW 2007-2010	502SW 2007-2010	503EW 2007-2010	504N&L 2007-2010
Const.	**5.717**	**3.686**	**4.073**	**3.836**	**3.809**
	*(21.587)****	*(23.777)****	*(27.461)****	*(25.549)****	*(25.915)****
ln (Wood Growth)	**0.053**	**0.033**	**0.033**	**0.035**	**0.037**
	*(3.796)****	*(2.057)***	*(2.210)***	*(2.217)***	*(2.363)***
ln (Rev. Received)[1]	**-0.114**	**-0.024**	**-0.055**	**-0.031**	**-0.022**
	*(-5.668)****	*(-1.925)**	*(-4.518)****	*(-3.000)****	*(-2.017)***
ln (Training)	**-0.004**	**-0.020**	**-0.022**	**-0.012**	**-0.012**
	(-0.481)	*(-1.796)**	*(-2.357)***	*(-1.184)*	*(-1.218)*
ln (Investments)	**-0.010**	**-0.013**	**-0.006**	**-0.019**	**-0.019**
	*(-2.247)***	*(-2.559)***	*(-1.293)*	*(-3.738)****	*(-3.626)****
ln (Contributions)[1]	**-0.079**	**0.048**	**0.002**	**0.010**	**0.008**
	*(-4.161)****	*(4.099)****	*(0.170)*	*(1.413)*	*(1.274)*
Adjusted R^2	0.23	0.08	0.22	0.04	0.04
DW	1.99	2.05	2.05	2.01	2.01
Observations	596	596	596	596	596

In brackets, t-statistics.
*** significant at 1%, ** significant at 5%, * significant à 10%
[1] Depending on the forest function.

Table 20 shows the second-stage regression results based on model 2. As we can see, the explanatory power almost doubles when looking at all forest functions together (overall M2). Globally, the results stay the same besides for total wood growth and contributions received. Total wood growth now exhibits a significant positive effect on efficiency, whereas contributions show a significant negative influence; moreover, the negative effect of training expenditures on efficiency is not significant anymore. When looking on the individual forest functions, we observe that the explanatory power of the model sharply decreases besides for function 502. Here (protective forests) it appears that training expenditures have again a significant negative impact on efficiency whereas contributions do not exhibit any significant effect. Nevertheless, we note that, as already before in case of model 1, contributions (for wood production) have a significant positive effect on efficiency in economic forests (501WW).

Conclusions

This study analyzes the technical efficiency of Swiss forestry firms on the basis of a balanced panel obtained from the TBN/REP data over the period 2007-2010 by applying a nonparametric method (DEA). The efficiency for wood production is calculated for all forest functions taken together but also for each forest function separately. Two models have been analyzed containing different input and output variables. Both models reveal an important potential in increasing the relative efficiency of Swiss forestry firms, mainly by reducing labor and capital inputs as well as administrative costs. When analyzing the efficiency by forest function it appears, as one might expect, that wood production in protective forests is generally the least efficient. On the other side, wood production in economic forests seems to be relatively less efficient when compared to leisure or nature and landscape forests.

A detailed benchmark analysis shows that efficient firms generally use less working and machine hours for producing wood. Moreover, their administrative costs are significantly lower than those of less efficient firms. The difference in terms of third-party services is not very strong, but the amount of contributions received is the higher the less efficient the firms. Furthermore, it appears that efficient firms generally spend less on investments (global spending) than less efficient firms. Finally, it can be shown that efficient firms generally have a higher turnover from wood production when compared to non-efficient firms, i.e., technically efficient firms are less diversified than less efficient firms. One reason might be that less diversified firms turn out to be more specialized in wood production than others.

Concerning the productive forest area, it appears that efficient firms, when compared to non-efficient firms, generally have a smaller productive forest area in protective forests but a larger one in nature and landscape forests. This result can be confirmed when investigating the number of efficient firms by forest function. When analyzing the firms' origins by forest region it can be shown that technical efficient firms in wood production mainly appear in the Mittelland. On the other side, the percentage of efficient firms from the Alps is the smallest. Difficult topological and climate conditions might be the main explanation for this result. When looking on the owners, it seems that efficient firms mainly belong to political communes and less to Bürgergemeinden. Finally, when looking at the production of wood by assortment, it appears that efficient firms normally sell more standing timber and produce more round wood (total), but less firewood, than less efficient firms.

Concerning the returns to scale it seems that, all forest functions combined, almost three quarters of the firms have passed an optimal size. In terms of average production (m^3), this optimal size seems to be between 2700 and 5900 m^3 (model 1). When checking for the productive forest area, it seems that the optimal size would lie somewhere between 600 and 1050 ha. When focusing on the individual forest functions, it appears that for the economic and productive functions, most of the firms have passed an optimal size for wood production. For economic forests, the optimum size would be between 1800 and 5000 m^3 (400 and 600 ha); for protective forests, the optimum size lies between 800 and 2900 m^3 (300 and 1000 ha). On the other side, when looking at the leisure and nature & landscape functions, it appears that three quarters of the firms are too small (in terms of wood production), and thus have an interest to increase their size.

The analysis of the relation of the efficiency scores with some selected financial variables showed that almost no link exists between the efficiency of the firms and their revenues; however, there seems to be a low but positive link between profits and efficiency. On the other side, and even though the relation appears to be weak, there seems to be a negative link between efficiency and investments as well as efficiency and contributions, during the period analyzed.

Finally, we analyzed the influence of some selected variables on the firms' efficiency. When looking at all forest functions together, the revenues received by a firm for work done for third parties, training expenditures, and total investments, have all a significant negative effect on efficiency. Depending on the model, contributions (for wood production) have either no impact or a negative impact on the overall efficiency (all forest functions taken together). On the other side, when analyzing only the economic forest it appears that contributions (for wood production) display a positive effect. The impact of wood growth on efficiency is less clear-cut: depending on the model there is either a positive effect (model 2) or no significant effect at all.

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8. An Econometric Analysis of Costs in Multi-output Forestry Firms in Switzerland (by Mehdi Farsi)

Technical appendix to the report:

Analysis of the production efficiency of the Swiss forestry firms with regard to the forest functions

Submitted to the

Federal Office for the Environment (FOEN)

October 2012, revised March 2013

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Abstract

This report provides an analysis of the cost structure of the Swiss forestry firms using data from a representative sample of 200 firms included in the Swiss Forestry Pilot Network (TBN/REP). The final regression sample is an unbalanced panel of 655 observations from 195 companies over a four-year period from 2007 to 2010. The multi-functionality of forestry firms has been considered with seven output measures. We use a combined Box-Cox logarithmic functional form to account for zero outputs with Box-Cox transformation while retaining the simplicity of logarithmic form for interpretation and comparison purposes. Further cost analysis has been carried out by a linear cost function with quantile regression method. The analysis provides a better understanding of the functioning of the Swiss forestry firms and the potential reasons behind the sector's apparent inefficiency with respect to their commercial role as the Switzerland's main supplier of wood. In particular, we explore the firms' hybrid characteristics in combining several public services with their core businesses namely wood harvest and production. We also examine the variation of costs across different regions, firm types and other characteristics. These variations can guide a meaningful classification of forestry companies to uniform classes that can be eventually used in a benchmarking analysis. The estimations also provide a measure of the unexploited economies of scale and the corresponding optimal size.

Introduction

The Swiss forestry industry has been increasing deficits over the last two decades. With increasing costs not covered by sufficient revenues, an industry with reasonable profits has been gradually transformed to a heavily subsidized industry. Today, government contributions consist of about a fifth of a typical forestry firm's revenues. Many observers have associated the decline of the industry's performance to hurricanes. However, the continuity of deficits over twenty years suggests that the industry might have structural problems that are potentially due to inefficiency and lack of competition. In fact, virtually all these companies are local monopolies that are often supported and financially covered by the municipalities and local governments. Previous studies indicate a substantial technical inefficiency in logging firms. The main caveat of these studies is their focus on timber production at the detriment of neglecting the firms' public service role in maintaining the Swiss forests.

It is argued that wood production is only one of several functions forestry firms provide. A better picture of the industry's performance requires a complete account of all forest services and the forestry's contribution in maintaining them. These services are classified into four main groups according to the forest's function: Production (provision of wood resources), Protection (of roads and villages in mountains and slopes), Leisure (providing a space of leisure and relaxation) and Landscape/Nature (natural beauty, biodiversity and environmental protection). Based on their principal function the Swiss forests are classified into four groups. The forests covered by any specific firm could include one or several groups among the remaining three categories.

In addition to differences in functions as defined above, forestry firms are characterized by considerable heterogeneity specific to their location, topography, vegetation and other environmental factors. Many of these factors could be unobservable or too complex to be taken into account as simple measures tractable in cost and production models. Therefore, benchmarking analyses that do not account for these differences might lead to biased efficiency estimates. An adequate cost analysis can be used to identify groups of firms that are relatively uniform hence reasonably comparable.

The analysis presented here is a first attempt of its kind to study the multi-functional features of the Swiss forestry firms with respect to costs. The data consist of financial and technical information from 200 forestry firms included in the pilot network of forestry firms known as TBN/REP network. This network consists of a representative sample of firms selected among more than two thousand firms operating throughout Switzerland's forests. The available data include an exceptionally detailed series of variables about various aspects of the forestry firms' activities. The focus is upon the firms' main activities related to wood production and the maintenance of forests. We use a Box-Cox functional form to estimate the multi-output forestry cost function. The results are used to estimate various elasticities and the economies of scale. In addition, we estimate a linear cost model with quantile regression method. The estimation results are used to identify differences in marginal costs among forest companies.

The rest of this report is organized into four sections. Section 0 describes the data. Section 0 presents the model specification and the methodology. Section 0 discusses the estimation results. Section 0 concludes the report with a discussion of the main results.

Data

The TBN/REP data include financial and technical information of about 200 forestry firms. The data is based on an analytical accounting procedure that records the costs, revenues and outputs in four functional categories namely, Production (provision of wood resources), Protection (of roads and villages in mountains and slopes), Leisure (providing a space of leisure and relaxation) and Landscape/Nature (natural beauty, biodiversity and environmental protection). For each activity one of the above categories is assigned according to the primary function aimed at by that activity. While the distinction between productive and protective functions are more or less clear, for other functions, there might be some ambiguities that leaves certain discretion to the firms in assigning their costs and outputs.

The data available to us is an unbalanced panel of 802 observations covering 229 firms over the four-year period from 2007 through 2010. After excluding observations with missing values for wood production and costs the sample is reduced to 796 observations from 228 firms.[1] There still remain a series of observations with missing values. The number of observations with missing values varies depending on the considered variables. In order to minimize the excluded records we conducted a correction procedure for variables that are more or less time-invariant: we changed a number of suspicious values to missing values and we completed a few missing values using the values for the same company in other years.[2] Our final regression sample covers 195 firms and includes 655 observations with non-missing values for all included variables.

[11] We excluded four observations from company ID# 18038 because of missing output (wood production) and costs, one observation from company ID# 18636 in 2010 because of missing output and also one observation from company ID# 60312 in 2007, because the recorded costs are less than half of the costs in all other years with little change in outputs.

[2] In 13 observations from 2007, the firm's region is miscoded. We completed these values using the data in years 2008 to 2010. In 10 observations the input factor prices (labor and capital) were missing in one year. The missing values were completed by averaging the corresponding firm's values over the remaining years with non-missing values. We identified two cases where the length of roads was miscoded (Companies ID number 62939 and 76658 in year 2009). We

Table 1 summarizes the distribution of the firms included in the regression sample by year and region. With the exception of the Alps in 2007, the observations are more or less evenly distributed over the sample period.

Table 1: Distribution of observations by year and region

	2007	2008	2009	2010	Total
Alpen	30	41	41	43	155
Jura	40	46	49	47	182
Mittelland	51	52	55	55	213
Voralpen	26	27	26	26	105
Total	147	166	171	171	655

The variables included in the cost analysis are listed in Table 1. The first variable listed is the dependent variable which is the total costs associated with the operation of the forest with respect to timber production. These costs include costs related to plantation and harvest as well as administration costs. Table 2 also provides a descriptive summary of the regression sample.

Table 2: Descriptive statistics (655 observations from 195 forestry firms)

Variable		Mean	Std. Dev.	Min	% of zero values	Max
C	Total cost (Frs) [i]	589'748	459'912	14'693		4'239'098
A^t	Total forest area ('00 ha)	11.035	11.008	0.500		73.000
PA^t	Productive (harvestable) area ('00 ha)	9.564	9.125	0.500		73.000
W^t	Total timber production ('000 m^3)	4.894	3.402	0.086		18.071
PP	Production possibility of timber ('000 m^3)	5.181	3.687	0.400		20.000
	Timber production by wood category ('000 m^3)					
W^1	Log	2.847	2.222	0.000	(.2%)	13.763
W^2	Firewood	1.209	1.193	0.000	(5%)	7.403
W^3	Industrial [ii]	0.713	1.016	0.000	(14%)	6.783

corrected the values based on other years. Comparing the values over the four years, we identified 42 observations mainly from 2007, in which the length of roads was not consistent with the data from other years and 10 companies (27 observations) that showed a suspicious change or zero values in their forest areas. We dropped all these observations.

	Forest area by the assigned primary function ('00 ha)					
A^1	Production	4.790	4.819	0.000	(15%)	26.070
A^2	Protection	5.084	10.659	0.000	(53%)	73.000
A^3	Leisure/Nature	1.157	2.124	0.000	(45%)	14.250
	Log production by the assigned primary function ('000 m^3)					
L^1	Production	1.941	2.098	0.000	(21%)	12.207
L^2	Protection	0.794	1.511	0.000	(58%)	11.018
L^3	Leisure/Nature	0.111	0.396	0.000	(81%)	5.114
	Non-log production by the assigned primary function ('000 m^3)					
N^1	Production	1.644	1.779	0.000	(21%)	9.236
N^2	Protection	0.334	0.637	0.000	(59%)	4.711
N^3	Leisure/Nature	0.070	0.281	0.000	(80%)	4.473
R	Length of roads (m/ha)	78.517	71.868	0.000	(4%)	542.000
	Input factor prices					
P^L	Labor (Frs/hr)	46.34	12.21	21.94		105.73
P^K	Non-labor (Frs/ha) [iii]	489.04	259.57	41.97		1727.24
C^{anc}	Cost share of ancillary services (%) [iv]	2.76	4.12	0.00	(25%)	31.29
S^{sub}	Revenue share of public contributions (%)	27.78	20.25	0.00	(2%)	91.84
S^{adm}	Share of administration costs (%)	13.04	6.18	0.00	(.2%)	65.03
S^{out}	Share of outsourcing costs (%)	27.28	18.56	0.00	(1%)	96.58
D^r	Road density (length per ha) [v]	0.17	0.24	0.00	(4%)	2.04
D^w	Wood density (harvest possibility) m^3/ha [v]	6.54	3.56	0.34		23.68

% of observations with zero value is in parentheses; Monetary values are in current Francs. *i*) Excludes costs of ancillary services; *ii*) Includes non-classified types; *iii*) Per forest's productive area; *iv*) Of total costs plus ancillary costs, *v*) Per total forest area.

Model Specification

Our analysis focuses on the costs of wood production. Therefore, our dependent variable (first variable in table 2 is the total costs included in the operation of the forest with respect to timber production. This includes plantation and harvest as well as administration costs,[3] but excludes all the expenses in relation with ancillary products and services[4] provided by the firms. Although the ancillary activities are excluded from the analysis, their indirect effect on costs of main activities will be explored.

The timber output can be classified into three main categories logs, firewood and industrial wood. The little remaining timber remains unclassified. We include the unclassified timber in the industrial category. In addition, the analytical accounting data allows a classification of timber production into four functional categories, namely the timber produced in relation with forests with productive, protective, leisure and nature/landscape functions. This implies that the total timber harvested is divided into four parts, one for each specific forest's function. This classification applies also to the forest area that is divided into four parts with respect to their main functions. Among the four categories, categories 3 and 4 (leisure and nature/landscape), especially the latter, are generally small and entail a large number of zeros. Therefore we decided to combine these two categories into one group. Moreover, as certain types of timber are relatively little in some of the functional categories (especially firewood and industrial wood) we decided to distinguish only two groups (logs and non-log wood) by functional categories (see Table 2).

As observed in Table 2, in any output category there is a number of observations with zero production. For instance in about 5 percent of the included firms do not produce firewood, and in about 14% there is no industrial wood. In more than half of the sample, there is no forest area associated with the protection function whereas the area associated with leisure/nature/landscape is absent in about 45 percent of the firms. In order to accommodate the zero values we need to avoid a logarithmic function. An alternative functional form is the Box-Cox transformation.[5] Here, in our main analysis we use a Box-Cox transformation for all output variables while keeping the dependent variable (costs) in logarithmic form.

The cost function specification requires input factor prices. Here, we consider two input factors; labor and non-labor.[6] Labor prices are defined as the aggregate hourly wage of the firm's employees. We use a residual approach for non-labor inputs. Namely, the capital price is defined as the non-labor costs divided by a physical measure of capital stock. Lacking the data for an accurate measure of capital, we used the forest's productive (harvestable) area as an aggregate proxy for the firm's capital inputs.

It is important to note that the Swiss forestry firms increasingly use outsourcing contracts for their timber production. That is, a substantial part of costs corresponds to the purchase of third-party services. As shown in Table 2, a typical average company's cost share of third-party services is about 27 percent. Outsourcing can go up to more than 90 percent of the activities related to wood production. The outsourcing costs are non-labor costs which are included in the residual cost of "capital". It is therefore important to note that the non-labor input in our model is an aggregate input that is distinguished from the labor employed by the forestry firm.

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[3] The administration costs include costs related to planning and the training of the employees.

[4] These product and services (*activités accessoires*) are offered by the forestry firm to third party buyers.

[5] Box-Cox transformation is a power transformation defined by $y^{(\lambda)} = (y^{\lambda}-1)/\lambda$, which covers a family of functions including the linear form when λ=1, and the logarithmic function as a limiting case when $\lambda \rightarrow 0$.

[6] We use non-labor inputs instead of capital inputs because much of the non-labor costs could be related to third-party services.

We have also included a number of explanatory variables in order for a better explanation of costs. These variables are listed in Table 2. We used a series of preliminary regressions to identify the variables that have a better explanatory power. These variables include fixed effects for years and regions. However, the year dummies were never statistically significant. So they have been excluded from the final regressions. We retained several specifications for our final analysis.

We used two main model specifications that differ in the specification of the forestry firm's outputs. In the first specification (models reported in Table 3) the output vector (y) includes W^1, W^2, W^3, A^1, A^2, A^3 and R, whereas in the second specification, the outputs are specified as L^1, L^2, L^3, N^1, N^2, N^3 and R (see Table 2). The first specification is based on the assumption that public service outputs are completely distinguished from wood production. In these models public services are measured as the forest area in three categories (A^1, A^2, A^3). In contrast in the second specification (models reported in Table 4) we assume that all forestry outputs can be measured in terms of volume of wood produced, but the nature of the service can be attached to the purpose of harvest. In these models two outputs (L^1, N^1) are solely related to economic (marketable) production. The remaining production (L^2, L^3, N^2, N^3) have public service objectives even though they result in revenues all the same.

In both model types, there is a seventh service namely the maintenance of roads and access to forests. This output is represented by the length of the main roads in the firm's service area (variable R as described in Table 2). Roads can be considered as the infrastructure for accessing the forest resources, hence an input variable. However, given that forestry firms are responsible for the maintenance of the main roads located in their service areas and these operations are relatively costly, we used the length of main roads as an output proxy.

In addition to outputs and input prices, we control for a series of cost drivers (vector Z) that could be classified as environmental and output characteristics. These cost drivers include two density variables for main roads and trees, namely the road density (D^r) and the wood density (D^w). Both density variables are expected to have a negative effect on costs because main roads facilitate the access, whereas higher wood density implies a higher production in a relatively small area. We also included the costs of ancillary services (S^{anc}) as a percentage of total costs (C) plus ancillary costs (see Table 2). The effect of this latter variable could be positive if providing ancillary products and services put a cost burden on the firm's main functions.

In alternative models we also include the share of public contributions (S^{sub}) as a percentage of the firm's total revenues as well as shares of administration costs (S^{adm}) and outsourcing costs (S^{out}) as a percentage of total costs (C). We have however excluded these share variables in the base models, because of the concern we had about their potential endogeneity. As we will see these variables are decision variables that might be adopted differently among various firms. For instance, the share of subsidies (public contributions) might be higher in companies that are relatively more costly. In this case, a positive correlation between subsidies and costs does not necessarily imply that the subsidies have a negative effect.

The general form of the adopted cost function can be written as:

$$\ln C = \beta_0 + \sum_{m=1}^{7} \beta_m y_m^{(\lambda)} + \sum_{n=1}^{2} \gamma_n \ln P_n + \sum_{k=1}^{K} \eta_k Z_k + \sum_{l=1}^{3} \delta_l D_l \qquad (1),$$

where $\beta_m, \gamma_n, \eta_k, \delta_l$ (m=0,1,…,7; n=1, 2; k=1,…,K; l=1, 2, 3) and λ are the model parameters, $y^{(\lambda)} \equiv \frac{y^{\lambda}-1}{\lambda}$ is the Box-Cox transformation of variable y, and the model's variables are defined as follows:

C: Total operating costs of the forestry firm (excluding the ancillary activities)

y_m (m=1,…,7): The outputs of a forestry firm classified in seven components

P_n (n=1, 2): Factor prices (labor and non-labor)

Z_k (k=1,…,K): A selection of output and environmental characteristics (cost drivers)

D_l (l=1, 2, 3): Three region dummies (omitted category: Midland).

Costs and all other monetary variables are in current Swiss Francs. We have imposed the linear homogeneity in factor prices namely, $\gamma_1 + \gamma_2 = 1$, by dividing the dependent variable (costs) and factor prices by the non-labor factor price (P^K). This restriction ensures that the cost function represents the real costs. After imposing this condition and adding a normal error term, $\varepsilon_{it} \sim N(0, \sigma_\varepsilon^2)$, the econometric model can be written as:

$$\ln\left(\frac{C_{it}}{P_{it}^K}\right) = \beta_0 + \sum_{m=1}^{7} \beta_m y_{m(it)}^{(\lambda)} + \gamma_1 \ln\left(\frac{P_{it}^L}{P_{it}^K}\right) + \sum_{k=1}^{K} \eta_k Z_{k(it)} + \sum_{l=1}^{3} \delta_l D_{l(i)} + \varepsilon_{it} \qquad (2),$$

where subscripts i and t denote the company and the year.

The regression coefficients can be used to estimate the output elasticities and the economies of scale according to the following expressions:

$$E_m = \frac{\partial \ln C}{\partial \ln y_m} = \beta_m \left(y_m\right)^{\lambda} \qquad (3),$$

$$ES = \left(\sum_{m=1}^{7} \frac{\partial \ln C}{\partial \ln y_m}\right)^{-1} = \left(\sum_{m=1}^{7} \beta_m \left(y_m\right)^{\lambda}\right)^{-1} \qquad (4),$$

where E_m is the elasticity of costs with respect to output y_m, and ES is the rate of the economies of scale. Scale economies exist if increasing production lowers average cost. Following Caves et al. (1981, 1984) we define economies of scale as the proportional increase in total cost resulting from a proportional increase in all outputs with all other factors being constant. We will have economies (resp. diseconomies) of scale if ES is greater (resp. lower) than 1. The optimal scale is identified from the equality ES =1.

In a complementary analysis we used a linear cost function in order to estimate the marginal costs of various outputs at different quantiles of the sample. In this analysis we initially used a quadratic cost function specified as:

$$C = \beta_0 + \sum_{m=1}^{7} \beta_m y_m + \sum_{m=1}^{7} \beta_{mm} y_{mm}^2 + \sum_{n=1}^{7}\sum_{m=1}^{7} \beta_{mn} y_m y_n + \sum_{l=1}^{3} \delta_l D_l \qquad (5).$$

In order to minimize the confounding effects of other variables and to facilitate a clear interpretation of marginal costs, we intentionally focused on output variables. However, given that our preliminary analyses indicated that most 2nd-order terms are almost always insignificant, we reduce the model to a parsimonious linear function as follows:

$$C = \beta_0 + \sum_{m=1}^{7} \beta_m y_m + \sum_{l=1}^{3} \delta_l D_l \qquad (6).$$

The purpose of this analysis is to identify the differences across forestry firms regarding their marginal costs. We used the quantile regression approach, an estimation method proposed by Koenker and Bassett (1978).[7] This method offers a systematic strategy for examining the entire distribution by modeling any given conditional quantile (percentile) of the distribution. The econometric cost model based on quantile regression can be written as:

$$C_{it} = \beta_0^{(q)} + \sum_{m=1}^{7} \beta_m^{(q)} y_{m(it)} + \sum_{l=1}^{3} \delta_l^{(q)} D_{l(i)} + e_{it}^{(q)} \qquad (7).$$

Here, q is a real number between zero and 1 ($0<q<1$) representing the adopted quantile, and superscripts (q) represent the parameters estimated at quantile q. The error term $e_{it}^{(q)}$ is the residual at observation i, estimated at quantile q. The main feature of the quamtile regression method is its robustness to outliers and to the distribution of the errors. We estimated the model at five quantiles q=.1, .3, .5, .7, and .9, respectively representing the 1st, 3rd …, and the 9th deciles with respect to costs.

Results

The regression results of the Box-Cox cost models are listed in Table 3 and Table 4. Models in Table 3 are based on the assumption that public outputs are completely distinguished from wood production, whereas the models in Table 4 assume that all forestry outputs can be measured in volume of wood produced, but the nature of the service can be attached to the purpose of harvest. The first observation is that most variables have the expected signs and show plausible effects. Secondly, all models have reasonable explanatory power as reflected in relatively low variance of the error term and the statistical significance of most coefficients. We can also observe that the hypothesis of logarithmic form (λ=0) is rejected across all models.

Models 2 and 4 are our base models. In models 3 and 5 we included additional variables related to the organization and management of the firm. In another variation (Model 1) we added three

[7] Quantile regression is gradually emerging in many empirical studies in economics. Koenker and Hallock (2001), Yu et al. (2003) and Koenker (2005) provide a variety of examples. Koenker (2005) considers production and cost frontiers as a compelling case among these applications.

interaction terms between public and "private" services. Our preliminary analyses showed that such interaction terms are mostly insignificant. Moreover, because the presence of interaction terms renders the interpretation of the main coefficients difficult, we preferred to delete these terms in our base models.

Overall, the regression results based on all five models are plausible in sign and magnitude (see Table 3 and 4). First, it is important to note that the Box-Cox parameters are significantly different from one and zero across all models, thus rejecting the linear and logarithmic models. Now, let us consider the non-transformed variables. The coefficients of input factor prices indicate a reasonable distribution of costs between labor and non-labor inputs.[8] All models point to an asymmetry of production factors against labor. However, it should be noted that here, the non-labor input price includes the outsourced services that also include labor. Therefore, these coefficients do not indicate a capital intensive production. In fact, in the interpretation of these coefficients by labor we mean employed labor or internal labor services and non-labor inputs includes all the remaining inputs.

The coefficient of non-labor input is not statistically significant across all five models. This can be explained by an unusually strong variation in cost shares. The data indicate that the share of non-labor costs vary from 12.8 to about 99.7 percent of total costs of wood production. The average share of non-labor cost is about 62.7 percent. This strong variation in the sample is due to great differences in outsourcing strategies among these companies. In terms of average shares, the models in Table 3 appear to be more consistent with the observed shares of labor and non-labor inputs.

The positive effect of ancillary services indicates that the companies with a higher share of these secondary services are relatively more costly. Across the five models, we can observe a coefficient of about .011 to .024, implying that one percentage point increase in the share of these services will create on average, an additional cost of 1.1 to 2.4 percent in total costs of wood production. Given that the cost of ancillary services is not included in the dependent variable (C), this result suggests that ancillary services are a cost burden for these companies. Considering the averages, we can conclude that the share of ancillary services is about 3% hence negligible for typical companies (see Table 2). However, if we consider the companies with a high share of ancillary services (up to 31%) this cost burden might become substantial. For instance, the results suggest that for a company whose ancillary services are about 10%, the additional costs compared to a similar company without those services is at least 20%.

The regional dummies indicate that wood production in the Alps is on average 25 to 50 percent more costly than those in the midlands, whereas the Jura represents about 10-15 percent less costly production. It is interesting to note that in both types of models, when additional variables (contribution, administration and outsourcing) are included the lesser costs in Jura practically vanish and become statistically insignificant (models 3 and 5). This suggests that the apparent lower cost in Jura is not a robust result. In contrast, the substantially higher costs in the Alps persist regardless of the model specification. Intuitively, this cost difference can be related to the difficulty of access and harvest in the steep slopes of the Alps.

[8] The coefficient of each factor price in a logarithmic cost function represents the cost share of that production factor.

Table 3: Regression results (Box-Cox models 1-3)

Dependent variable: **ln*C***: logarithm of total costs	Model 1		Model 2		Model 3	
Outputs (transformed variables)						
W^1: Wood production (logs)	0.212	**	0.099	**	0.100	**
W^2: Wood production (firewood)	0.224	**	0.177	**	0.132	**
W^3: Wood production (industrial)	0.141	**	0.118	**	0.128	**
A^1: Public service (productive forest)	0.170	**	0.101	**	0.108	**
A^2: Public service (protective forest)	0.143	**	0.092	**	0.094	**
A^3: Public service (leisure/nature/landscape)	0.049	**	0.039	**	0.042	**
R: Public service (roads)	0.005	**	0.010	**	0.007	**
Interaction of A^1 with total timber output (W^t)	-0.021	**	_		_	
Interaction of A^2 with total timber output (W^t)	-0.015	**	_		_	
Interaction of A^3 with total timber output (W^t)	-0.005		_		_	
Non-transformed variables						
$\ln(P^L)$: Labor input price in logs	0.285	**	0.323	**	0.304	**
$\ln(P^K)$: Non-labor input price in logs	0.715		0.677		0.696	
S^{anc}: Share of ancillary services	0.017	**	0.018	**	0.011	**
Alp: Region dummy for the Alps	0.245	**	0.381	**	0.255	**
Pre-Alp: Region dummy for Pre-Alps	0.029		0.042		-0.001	
Jura: Region dummy for Jura	-0.096	**	-0.105	**	-0.026	
D^r: Road density	-0.425	**	-0.685	**	-0.725	**
D^w: Wood density	-0.017	**	-0.015	*	-0.017	**
S^{sub}: Revenue share of public contributions	_		_		0.002	**
S^{adm}: Share of administration costs	_		_		-0.012	**
S^{out}: Share of outsourcing costs	_		_		-0.010	**
α_0: Intercept	7.132	**	7.250	**	7.675	**
λ: Box-Cox parameter	0.711	**	0.619	**	0.622	**
λ_{min}: Lower bound (95% confidence intreval)	0.657		0.561		0.572	
λ_{max}: Upper bound (95% confidence intreval)	0.766		0.677		0.672	
σ_ε: Standard deviation of the stochastic term	0.286		0.315		0.266	

** significant at p<.05; * significant at p<.10

Table 4: Regression results (Box-Cox models 4-5)

Dependent variable: **ln*C***: logarithm of total costs	Model 4		Model 5	
Outputs (transformed variables)				
L^1: Log production (productive forest)	0.167	**	0.181	**
L^2: Log production (protective forest)	0.172	**	0.213	**
L^3: Log production (leisure/nature/landscape)	0.162	**	0.078	
N^1: Non-log production (productive forest)	0.225	**	0.200	**
N^2: Non-log production (protective forest)	0.171	**	0.114	**
N^3: Non-log production (leisure/nature/landsca.)	0.184	**	0.235	**
R: Public service (roads)	1.130	**	0.955	**
Non-transformed variables				
$\ln(P^L)$: Labor input price in logs	0.456	**	0.447	**
$\ln(P^K)$: Non-labor input price in logs	0.544		0.553	
S^{anc}: Share of ancillary services	0.024	**	0.018	**
Alp: Region dummy for the Alps	0.511	**	0.342	**
Pre-Alp: Region dummy for Pre-Alps	0.023		-0.043	
Jura: Region dummy for Jura	-0.150	**	-0.050	
D^r: Road density	-0.918	**	-0.938	**
D^w: Wood density	-0.046	**	-0.048	**
S^{sub}: Revenue share of public contributions	_		0.003	**
S^{adm}: Share of administration costs	_		-0.013	**
S^{out}: Share of outsourcing costs	_		-0.009	**
α_0: Intercept	10.201	**	10.247	**
λ: Box-Cox parameter	0.714	**	0.729	**
λ_{min}: Lower bound (95% confidence intreval)	0.644		0.660	
λ_{max}: Upper bound (95% confidence intreval)	0.784		0.798	
σ_ε: Standard deviation of the stochastic term	0.384		0.349	

** significant at p<.05; * significant at p<.10

The difficulty of access is an important driving factor in costs. This is also shown by the negative and significant effect of the variable *road density*. The coefficient of this variable varies between -.4 and -.9 and indicates that adding 100 meters road in a hectare of forest is equivalent with 4 to 9 percent decrease in costs of wood production. That is, forests with a better road network (higher road density) have considerably lower costs. Another access-related factor is the density of woods.

As shown by a negative coefficient varying from -.02 to -.05, the wood density has a negative effect on costs. For instance, forests that have 1 cubic meter of wood per total forest area represent about 2 to 5 percent lower costs in wood production.

The three variables included in models 3 and 5, could have policy implications. First, the effect of public contributions is negative and significant. This suggests that the firms that benefit from more public contributions (subsidies etc.) are relatively costly. The estimated coefficients suggest that for instance, any ten percentage point increase in public contribution's revenue share, the costs show an increase of 2 or 3 percent in total costs. Given the shares observed in the sample (average share of 28% and the standard deviation of 19%) a difference of 10 percentage points in contributions is quite plausible. Therefore the magnitude of the effect is fairly considerable. This result suggests that the public contributions have a negative impact on the firms' cost efficiency.

In contrast, the shares of administration costs and outsourcing costs have a negative and significant effect suggesting that for instance, ten percentage point increase in these costs can be associated with about ten percent decrease in total costs. This result implies that the firms that spend more on administration costs (including management, training etc.) as well as those that have a larger outsourcing share are comparatively more efficient in terms of total costs.

Before turning to the interpretation of output variables, it is worth noting that the interaction variables included in model 1 (see Table 3) indicate several interesting patterns. First, all negative interaction effects indicate cost-complementarity between forest areas and timber production. The effect is however statistically insignificant in the case of forest areas whose primary functions are leisure and nature. In other words, larger forest areas with production and protection functions correspond to relatively lower costs of timber production. This result can also be interpreted as a synergy between timber production and certain public-service functions namely, the maintenance of productive and protective forests.

In order to interpret the coefficients of the rest of the transformed variables (output variables) we use output elasticities. Elasticities represent the effect of a proportional change in the explanatory variable on total costs measured in a proportional manner. The output elasticities can be estimated using Equation (3). As can be seen in this equation, the elasticity depends directly on the output level. Our estimations indicate that the output elasticities vary considerably across firms. Table 5 provides a list of output elasticities estimated according to models 2 and 4. These values are calculated at corresponding sample means (excluding zero values in each case).

The numbers listed in Table 5 (model 2) indicate a more or less similar elasticity with respect to logs and firewood, but a lower effect of industrial wood. These numbers suggest for example, that a 10% increase in logs or firewood production creates on average, about 2% increase in total costs. The same increase in industrial wood production causes on average, about 1% increase in costs. The public service functions show a greater variation. Namely, ten percent increase in productive area implies about 3% increase in costs, whereas a similar increase in protective areas induces about 4% increase in costs. The lowest effect can be assigned to forest with leisure/nature function in which 10% increase in area corresponds to only 0.6% extra costs. Finally the cost effect of roads is relatively high: a 10% increase in the length of roads results in about 1.6% increase in total costs. Overall, the elasticities obtained from model 2 suggest that protective function is the most costly function, followed by the maintenance of the productive forest. The production of wood (logs and firewood) comes only at the third place, followed by maintenance of roads and then the production of industrial wood and finally the cheapest function, leisure/nature.

Table 5: Output elasticities based on Box-Cox models

Output elasticities at corresponding sample means [i]	Model 2	Model 4
W^1: Wood production (logs)	0.190	_
W^2: Wood production (firewood)	0.205	_
W^3: Wood production (industrial)	0.105	_
A^1: Public service (productive forest)	0.294	_
A^2: Public service (protective forest)	0.401	_
A^3: Public service (leisure/nature/landscape)	0.061	_
L^1: Log production (productive forest)	_	0.316
L^2: Log production (protective forest)	_	0.271
L^3: Log production (leisure/nature/landscape)	_	0.111
N^1: Non-log production (productive forest)	_	0.379
N^2: Non-log production (protective forest)	_	0.148
N^3: Non-log production (leisure/nature/landscape)	_	0.087
R: Public service (roads)	0.155	0.190

[i] Zero values are excluded in calculating sample means.

Model 4 differentiate the output elasticities with respect to the type of wood and the forest function. The elasticities provided in Table 5 (model 4) indicate the highest effect for production in productive forest: ten percent increase in log and non-log output result in 3.2% and 3.8% cost increase respectively. Production in protective forest has the second rank in costs with an elasticity of .27 for logs and .15 for non-log production. Finally the cheapest production occurs in the forest with leisure/nature functions with elasticity of 0.11 and .09 respectively for logs and non-log production. These results are all intuitively explainable by the fact that the timber production is focused in productive areas. Higher density of production implies higher elasticities.

The estimated rate of economies of scale (*ES*) based on model 2 is plotted in Figure 1. This rate is calculated for each observation using Equation Abstract. The values of ES are plotted against the total production volume and also the forest area. These figures indicate that overall the optimal scale of production is at about 5000 m^3 production with a forest of about 1000 hectares. However, our further analysis suggests that the optimal forest area in firms that provide uniquely a public service could differ from those dedicated to wood production.

Figure 1 depicts the economies of scale by the firm's functional specialization. This figure shows that firms uniquely providing a public service could reach their optimal size between 2000 and 3000 hectares at a scale more than twice other forestry firms. However, the optimal size in terms of production volume remains more or less similar, that is, about 5000 m^3. The difference in area size can be explained by the fact that uniquely public-service forests (such as protective forests located on mountain slopes) need a relatively large surface to reach the optimal production volume.

Figure 1: The economies of scale (Model 2)

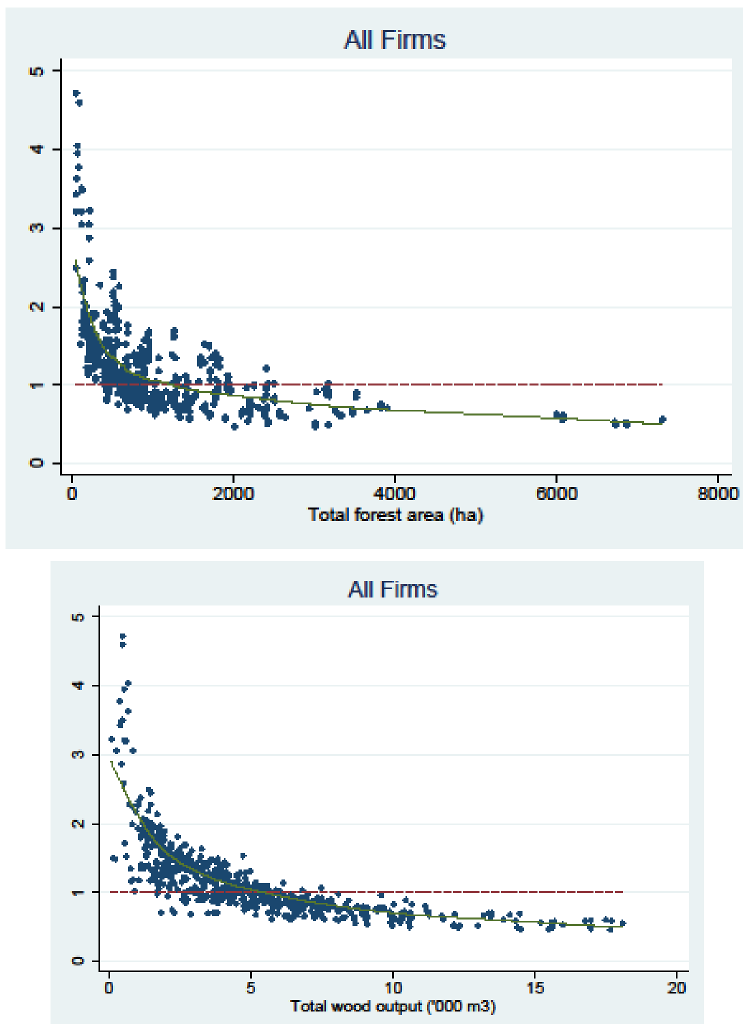
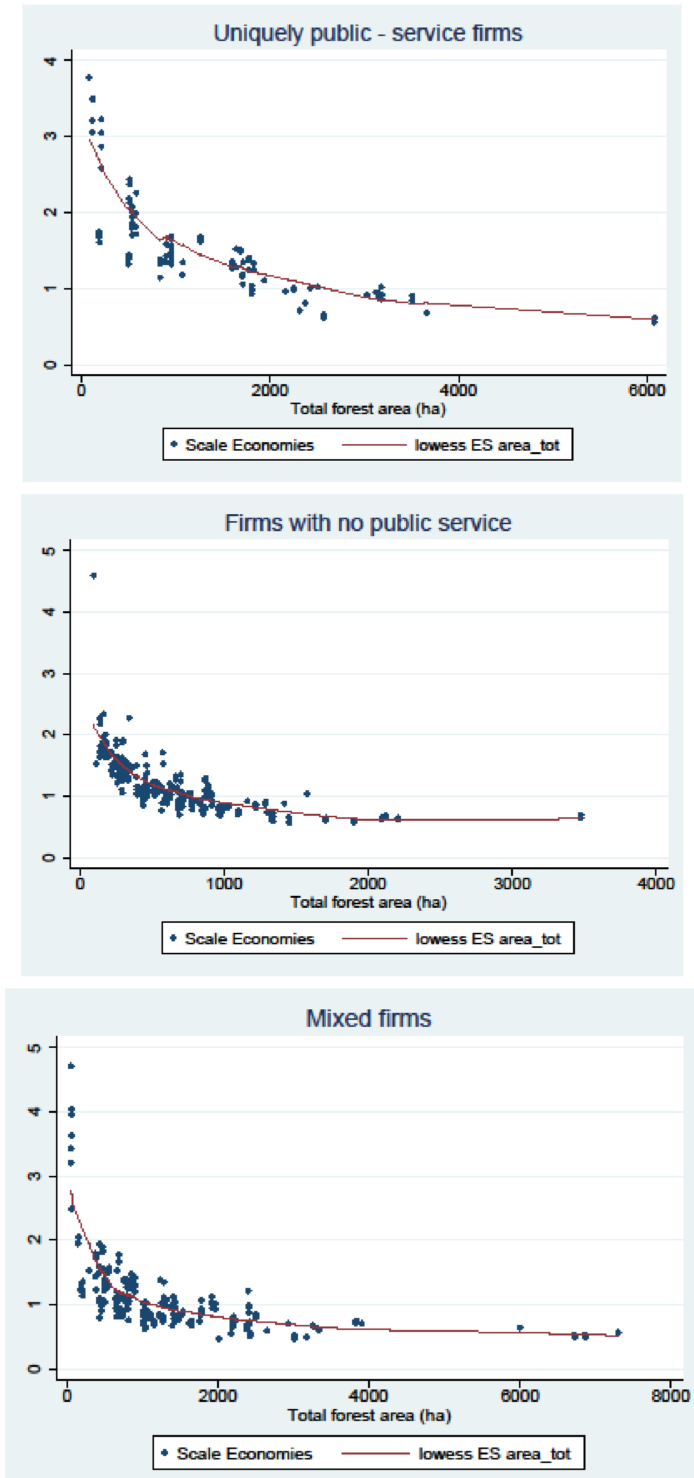


Figure 2: The economies of scale (Model 2)



The results of the linear cost models with quantile regression are given in Table 6 and table 7. These estimated coefficients in the linear model can be directly interpreted as marginal costs. The deciles represent the heterogeneity in forests with respect to unobserved costs. Therefore, the higher deciles (columns to the right) represent forest companies that have a higher level of complexity and difficulty in harvest and production. The considerable differences observed across various columns in both tables indicate that the forest companies are characterized by strong heterogeneity in costs.

The results shown in Table 6 are related to the model that distinguishes between timber production and public service functions. These numbers indicate that the marginal cost of 1 cubic meter of wood in form of logs can vary from 68 to 92 Frs depending on the forest company. The marginal cost of production of firewood is relatively higher varying from 76 to 168 Frs/m^3. The industrial wood is the cheapest production with a marginal cost of 58 to 86 Frs/m^3. An interesting observation is that in the case of industrial wood the complexity of production could be independent of firewood and log production costs. For instance the highest costs of log and firewood (decile 9) correspond to relatively cheap industrial wood.

In terms of areas (Table 6), the maintenance of productive areas is a relatively costly public service with a marginal cost of 120 to 200 Frs/ha. The maintenance of protective areas comes at the lowest marginal cost with about 40 to 180 Frs/ha. The estimation results indicate an interesting pattern of variation in marginal costs of maintenance with leisure/nature function. These costs show a wide range variation from about zero (in decile 1) to 340 Frs/ha in the most complex environments (decile 9). The last output variable is the maintenance of roads. This function has a marginal cost varying from about 170 to 440 Frs/km.

Table 6: Quantile regressions I (dependent variable: *C* in 1000 Frs)

	Decile 1		Decile 3		Decile 5		Decile 7		Decile 9	
W^1	68.41	**	69.23	**	76.88	**	84.17	**	92.29	**
	(9.95)		(5.19)		(6.89)		(7.92)		(20.37)	
W^2	75.75	**	89.59	**	115.85	**	127.51	**	167.81	**
	(10.08)		(9.29)		(5.26)		(17.30)		(39.42)	
W^3	58.26	**	85.65	**	84.02	**	75.53	**	63.01	**
	(16.01)		(7.55)		(6.60)		(9.38)		(25.80)	
A^1	15.32	**	12.48	**	11.58	**	11.66	**	20.26	**
	(3.30)		(3.25)		(2.62)		(4.44)		(5.01)	
A^2	3.64		8.59	**	9.31	**	9.18	**	17.43	**
	(2.39)		(2.15)		(0.88)		(1.67)		(5.22)	
A^3	-2.21		8.67	**	14.33	**	22.40	**	34.34	**
	(6.37)		(4.15)		(6.06)		(9.04)		(13.05)	
R	0.17		0.31	**	0.31	**	0.44	**	0.23	
	(0.10)		(0.09)		(0.10)		(0.18)		(0.20)	
Alp	75.06	**	80.90	**	116.97	**	153.42	**	56.11	
	(37.59)		(26.49)		(27.29)		(32.96)		(55.31)	
Pre-Alp	48.44	**	42.07	**	26.09		20.69		-83.36	*
	(13.76)		(17.25)		(18.54)		(25.41)		(45.93)	
Jura	-47.23		-39.61	**	-43.67	**	-43.11	*	-127.18	**
	(42.45)		(10.32)		(13.98)		(23.43)		(47.30)	
α_0	-41.47		-27.37	*	-17.42		-2.33		82.56	
	(26.64)		(15.58)		(16.32)		(22.89)		(52.24)	
Pseudo R^2	0.468		0.529		0.553		0.570		0.585	

Standard errors are given in parentheses; ** significant at p<.05; * significant at p<.10

Table 7: Quantile regressions II (dependent variable: *C* in 1000 Frs)

	Decile 1		Decile 3		Decile 5		Decile 7		Decile 9	
L^1	78.53	**	78.75	**	98.42	**	102.60	**	130.16	**
	(7.79)		(6.01)		(6.06)		(6.96)		(18.97)	
L^2	52.66	*	92.99	**	107.93	**	115.75	**	126.86	**
	(28.26)		(16.07)		(12.01)		(9.72)		(34.09)	
L^3	34.58		51.53		77.40		100.56		115.39	*
	(22.06)		(48.82)		(58.90)		(74.06)		(60.53)	
N^1	75.20	**	93.51	**	95.21	**	107.03	**	119.90	**
	(8.77)		(6.76)		(7.76)		(9.70)		(24.94)	
N^2	88.55	**	115.03	**	151.66	**	183.95	**	242.76	**
	(42.33)		(34.66)		(20.81)		(25.49)		(81.99)	
N^3	179.20	**	156.18	**	142.31		259.75	**	385.11	**
	(27.59)		(42.99)		(91.02)		(108.59)		(159.58)	
R	222.41	**	198.04	**	231.46	**	306.24	**	181.85	
	(61.06)		(69.13)		(101.65)		(154.08)		(364.47)	
Alp	87.77	**	95.90	**	128.70	**	161.80	**	179.31	**
	(37.90)		(34.60)		(40.43)		(26.57)		(89.29)	
Pre-Alp	30.10		24.67		-2.80		-28.81		-79.24	
	(23.91)		(23.08)		(12.54)		(24.21)		(54.15)	
Jura	-21.73		-7.34		-8.10		-17.43		-100.95	*
	(15.51)		(8.63)		(11.93)		(20.00)		(58.75)	
α_0	-19.90		2.49		13.52		33.36	*	109.09	*
	(15.61)		(9.98)		(10.66)		(17.24)		(60.09)	
Pseudo R^2	0.418		0.483		0.512		0.537		0.550	

Standard errors are given in parentheses; ** significant at p<.05; * significant at p<.10

Turning to Table 7, we can explore the variation of marginal costs of production by the type of wood and the harvested forest. The first observation suggests that the marginal cost differences are mainly in the non-log production. The log production cost in productive forests varies from 79 to 130 Frs/m^3. The corresponding costs in protective forests are only slightly different varying from 53 to 127 Frs/m^3. The marginal cost of log production in forests with leisure/nature function is mostly insignificant. This result can be explained by the fact that the log production in these areas is limited to negligible volumes.

In contrast, the non-log timber that can be harvested in all three forest types shows a great variation in marginal cost. For instance, in productive areas the marginal cost varies from 75 to 120

Frs/m^3, and in protective areas it varies from 89 to 243 Frs/m^3. Finally, with a marginal cost varying from about 150 to 385 Frs/m^3, the non-log production is the most costly in forests with leisure/nature functions.

The dummy regions (both Table 6 and Table 7) indicate the Alps with highest costs and Jura with the least total costs. Note that the region dummies cannot be interpreted in terms of marginal costs. They only show the average difference in total costs in each decile. For instance in decile 9 according to the first model (Table 6) a typical forest company in the Alps (resp. Jura) is about 180,000 Frs more expensive (resp. 101,000 Frs cheaper) than a similar company in the Midlands or the Pre-Alps.

Overall, the quantile regression results point to a great variation of production costs among forest companies that are not related to cost-efficiency but to the factors such as environmental difficulty that are beyond the management's control. In particular, the results suggest that the greater differences are related to timber production in protective forests and also the forests with the leisure/nature function. Moreover, the maintenance of these two types of forest shows a great variation in marginal costs. Among the types of wood, it is the firewood production that represents the highest variation in marginal costs.

Conclusions

We analyzed the cost structure of about 200 forest companies extracted from the Swiss Forestry Pilot Network (TBN/REP). We performed two separate analyses with a Box-Cox cost function and a quantile linear cost model. The first analysis is aimed at identifying the cost drivers and estimating the average effects as well as assessing the variations in the economies of scale and optimal size. The Box-Cox transformation accommodates the observations with zero outputs. In the second analysis we employ a relatively simple functional form but a refined econometric model in order to explore the patterns of heterogeneity in marginal costs across different companies.

Both analyses provide plausible results in terms of signs and magnitudes of the coefficients. Among the main results we would like to mention the following:

- Forest companies are characterized by a great variation in outsourcing. The share of outsourcing while being about 30% on average varies from about 0 to about 100 percent of the firm's activity. About half of the companies in the sample outsource more than a quarter of their activities (measured in costs) and about 10 percent outsource more than half. Any adequate analysis of costs and performance should account for these differences.
- Our analysis indicates a positive and significant cost effect for ancillary (annex) services, suggesting that these activities produce an additional burden for forest companies. This burden could be substantial for certain companies with high share of annex activities.
- The forest companies in the Alps are about 25 to 50 percent more costly than other regions.
- The harvest and production in areas with higher density of road per hectare of forest and also higher wood density is on average less costly.
- Public contributions show a negative impact on cost-efficiency. In contrast, the share of administration costs and the extent of outsourcing have both positive effects on cost-efficiency.
- The analysis suggests certain synergies in the form of cost-complementarity between public service functions and timber production.
- The estimated rate of economies varies among different companies. However, we can conclude that a typical average company in the TBN sample exploits all the economies related to scale. That is the optimal size corresponds approximately to the average size of TBN firms.

There are obviously small companies that can benefit from expanding their size through merger or joint activities with similar firms.

- We can estimate an optimal size. In terms of the production volume, the optimal size is obtained at about 5000 cubic meters of timber production per year. In terms of the forest area this is approximately equivalent to 1000 hectares, but might reach higher levels in forests that are uniquely of public-service use.
- The forest companies in the sample show a great degree of unobserved heterogeneity in marginal costs. It is likely that these cost differences are not due to differences in companies' performance. Rather, these differences are probably related to environmental and complexity factors that are beyond the firm's control.
- The greatest variation in marginal costs is related to timber production and maintenance function in protective forests but also in forests with the leisure/nature function. In terms of type of wood, the firewood production shows the highest degree of heterogeneity in marginal costs.
- We have identified the marginal cost of timber production for a median typical company but also at four other representative cost deciles. The marginal costs for a median company are estimated as follows: 77, 116 and 84 Frs/m3 respectively for logs, firewood and industrial wood; 98 and 108 Frs/m3 for log production in productive and protective areas respectively; and 95 and 152 Frs/m3 for non-log production in productive and protective areas respectively.
- Similarly, median marginal costs of public-service functions are estimated as follows: 116 Frs/ha for maintenance of productive forest, 93 Frs/ha for protective forest and 143 Frs/ha for forests with the leisure/nature function.

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9. Costs Analysis and Economies of Scale in the Swiss Forest Industry (by Géraud Krähenbühl)

Technical appendix to the report:

Analysis of the production efficiency of the Swiss forestry firms with regard to the forest functions

Submitted to the
Federal Office for the Environment (FOEN)

October, revised in April 2013

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Abstract

This short report studies the cost structure of forestry firms in Switzerland. Data come from the Swiss Forestry Statistics gathering information about 1'896 firms over a period of 7 years. A total of 10'857 observations are available from 2004 to 2010. This enables the analysis of the four specific regions separately from each other. A translog cost function is chosen and two outputs, production of wood and total area under management, are considered. No input price is incorporated in the model because of lack of available and reliable information. Results show strong heterogeneity between the different regions, but also within each one of them, coming from the very different environments, such as production and harvesting conditions. Calculated economies of scale give slightly different conclusions for each region but generally suggest that increasing size of forestry firms in Switzerland would be efficient and profitable, by decreasing overall costs and, at the same time, the dependency of the industry to subsidies.

Introduction

Economies of scale are computed based on information gathered by the Swiss Forestry Statistics of 1905 forestry firms, from 2004 to 2010, for a total of 10'857 observations.

The focus is put on the different regions of Switzerland, on their structure of costs functions and on economies of scale. First, the results clearly show the usefulness of the data, allowing for example to have region specific regressions. The analysis, using a translog cost function and simple OLS, gives very different results and coefficients for the four regions that are Jura, Mittelland, Voralpen and Alpen (Nord and South Alpen were merged together). The main reasons of these heterogeneous results are to be found in the various environments faced by firms between each region, but also within a region, which could explain the sometimes relatively low significance of estimates. Nevertheless, the results generally suggest that increasing the size of firms might have a positive impact on total costs, which could then lower the dependency of the forest industry to subsidies in all regions of Switzerland. This is supported by the fact that many firms are very small, surely too small to be possibly managed efficiently, and facing fixed costs that are too large.

Other statistical methods such as random or fixed effects model give similar results (not shown in this paper). The main contribution of this paper is to use the Swiss Forestry Statistics to analyze costs functions of the forestry industry. An important observation that can be drawn from the analysis is again the heterogeneity of the industry across regions. From a political point of view, this means that different regions deserve different policies. The main drawback of this study is surely the lack of information concerning the inputs prices, which can be a potential problem and source of inconsistency and biased estimates, coming for example from a possible omitted-variable bias.

Data

The data available come from the Swiss Forestry Statistics containing basic information of 1971 firms over a 7-year period, from 2004 to 2010. The data encompass productive and non-productive area, production of different types of wood, region and type of owners. The available information also includes some of the most important financial information: total costs and revenues of the firms, as well as subsidies and outsourcing costs. The Statistics has existed for a very long time and information is available well before 2004. However, this study focuses on this period as the methodology of the Statistics has deeply changed in 2004, which makes it difficult to reconcile the data and create a consistent time-series. For consistency reasons, data of 2003 and before were thus not considered.

Out of the 1971 firms, 66 were completely removed from the sample because either costs, total production of wood, or revenues were equal to 0. A translog cost function is estimated and as it takes the logarithm of both costs and production of wood, this would obviously create a problem. Although some procedures exist to circumvent it, the observations considered represent a small part of the data. Thus, it was decided to drop them. This represents an overall reduction of 1’335 observations. Observations with no revenues were also dropped since the ratio of subsidies over revenues is computed and used as an independent variable. Table 1 summarizes the distribution of the data over the years and regions. One can easily recognize that the numbers of observations for each region are largely sufficient to create region specific regressions.

Table 1: Distribution of observations by year and region

	2004	2005	2006	2007	2008	2009	2010	Total
Jura	368	359	363	364	367	342	339	2501
Mittelland	516	493	491	479	470	455	456	3360
Voralpen	325	326	336	316	308	285	282	2178
Alpen	415	420	412	409	409	373	380	2818
Total	1624	1598	1602	1568	1554	1454	1457	10’857

The 7-years unbalanced panel data is decomposed in table 2 by number of years available for each firm. More than half of the firms have information available over the entire period, which represents more than 80% of all observations used.

Table 2: Number of years available for each firm

# Years	1	2	3	4	5	6	7	Total
# Firms	124	90	121	114	129	137	1’181	1’896
# Observations	124	180	363	456	645	822	8’267	10’857

Model Specification

For the sake of simplicity, the model presented here contains only two outputs. Calculations have been done at a more disaggregate levels but conclusions are similar. The forestry industry is thus assumed to produce two outputs: wood, which is defined as the sum of all types woods produced (in volume), and area, which is the total area (addition of productive and non-productive ones). Since no reliable data were found for the prices of inputs, none are introduced in the model. It is then important to note that this can potentially distort the results by, among others, omitted-variable bias and thus possibly lead to inconsistent and biased estimates. The results are therefore to be taken with caution.

The costs are assumed to follow a translog cost function, which can be generally defined as

$$\ln(C_{it}) = \beta_0 + \sum_{m=1}^{M} \beta_m \ln(z_{m,it}) + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M} \beta_{mn} \ln(z_{m,it})\ln(z_{n,it}) + \sum_{n=1}^{N} \delta_n Q_n + \sum_{k=1}^{K} \gamma_n D_n$$

where Cit represents total costs of the firm i at time t, and zm,it is the output or input price m. In this paper, there are only two outputs and no input information, so M=2, with wood production and area. Matrices Q and D include descriptive variables about the firms. In the model presented below Q contain two ratios describing firms (productive over total area and subsidies over total revenues), and D encompasses all dummies of years, regions (if regression over Switzerland) and types of owners (public and private). From this, the econometric model is given by

$$\ln(C_{it}) = \beta_0 + \beta_w \ln(y_{w,it}) + \beta_A \ln(y_{A,it}) + \tfrac{1}{2}\beta_{ww} \ln(y_{w,it})^2 + \tfrac{1}{2}\beta_{AA} \ln(y_{A,it})^2$$

$$+\beta_{wA} \ln(y_{w,it})\ln(y_{A,it}) + \sum_{n=1}^{N} \delta_n Q_n + \sum_{k=1}^{K} \gamma_n D_n + \varepsilon_{it}$$

The variables y_w and y_A stand for the aggregated production of wood and area, respectively, and ε_{it} are the error terms of the regression.

The overall economies of scale (ES) are then defined by

$$ES = \frac{1}{\frac{\delta \ln(C)}{\delta \ln(y_w)} + \frac{\delta \ln(C)}{\delta \ln(y_A)}}$$

It follows that there are economies of scale when $ES > 1$ and diseconomies of scale when $ES < 1$. With two outputs, as stated above, and using the translog cost function, we get the following equality for the calculation of the economies of scale:

$$ES_{it} = \frac{1}{\beta_w + \beta_A + 2\beta_{ww} \ln(y_{w,it}) + 2\beta_{AA} \ln(y_{A,it}) + \beta_{wA}\left[\ln(y_{w,it}) + \ln(y_{A,it})\right]}$$

Results

Five regressions based on the econometric model defined above are made separately for five regions: Switzerland, Jura, Mittelland, Voralpen and Alpen. The large number of observations available enables to create region specific regressions, which is undeniably a great contribution of the Swiss Forestry Statistics. They were done using simple OLS and Random Effects model. However, since results are very similar, only the OLS estimates are presented. Coefficients of the regressions are given in table 3.

Overall, the results show very divergent cost structures for each of the regions considered. Even though there are similarities concerning different variables, the coefficients show the very significant differences of environments and realities among regions. This first observation might already have some implications on policies, as this considerable heterogeneity suggests that each region should have its own rules and policies, or that these could be applied slightly differently, according to their respective circumstances. In all cases this highlights clearly the fact that heterogeneity is an important issue and should be kept in mind.

The regressions are also quite dissimilar on several aspects. In this paper, the most important point about the regressions is the five first coefficients of each regression, which describes how total costs evolve with respect to outputs. The results are very heterogeneous across regions. The total area is the one output having a very different impact depending on the region as it can be either significantly positive or significantly negative.

Outputs coefficients and economies of scale

It is clear from the equation of overall economies of scale defined above, that when productions of wood and area vary, what drives economies or diseconomies of scale are the second-order terms β_{ww}, β_{AA}, and β_{wA}.

Because of the values and often non-significance of these second-order terms, economies of scale are subject to discussion, as an increase in the production of wood or area does generally not lead to a *decrease* in the economies of scale, as the economic theory suggests. This might come from the fact that this model is somehow too simplistic, maybe due to the lack of some important explanatory variables, or because some aggregation, such as wood production, is maybe not fully appropriate.

The exception of this general observation is Jura, where an increase in output of wood actually leads to a decrease in economies of scale. In this regression, the theoretical optimal size in term of wood production in Jura lies somewhere between 500 to 1’500 m^3 per year and around 150 to 350 hectares. According to the model and over these levels, the firms would experience diseconomies of scale. The median in Jura is 1’555 m^3 for the production of wood, and 349 hectares for the total area, which implies that most of the potential economies of scale are already used for the sample considered. However, the data do not consider forestry firms below 50 hectares, where lies the highest potential of relative cost reduction through increased size, and which represent a large number of firms.

These relatively large ranges of optimal sizes might come from different factors. It can be that the heterogeneity across firms in Jura is high and therefore some might experience diseconomies of scale sooner than others. All types of constraints surely differ significantly as well. It might also come from the fact that a large range exists under which overall economies of scale is fairly equal to 1, meaning there is neither economies nor diseconomies of scale.

Concerning Mittelland and Voralpen regions, results are quite different. It appears that the interaction term is not significant, which makes it then difficult to interpret the final results concerning the theoretical optimal size. In Mittelland, second-order term of wood production is neither significant, meaning the only conclusion related to economies of scale that can be extracted is that wood production does not seem to affect them at all. The Voralpen region has a significant second-order term for wood production, implying a decreasing return to scale according to this output. From the point of view of the area, the conclusion is different, as leaving the production of wood constant and increasing the area would in fact, according to the model, increase the economies of scale, such that there would theoretically be not point above which diseconomies of scale would appear. Of course, the model is here very questionable from a theoretical point of view and previous remarks and caution about heterogeneity and model specification discussed above should be more than ever kept in mind. Anyhow this is hypothetical. Increasing the production of wood creates slightly different results even though the general conclusion stays similar, which is that creating one firm managing all forest areas would be more efficient in those regions.

Table 3: Coefficients of regressions

Variable	Switzerland		Jura		Mittelland		Voralpen		Alpen	
β_w: ln (wood)	0.808	***	0.971	***	0.577	***	0.937	***	0.721	***
β_A: ln (area)	0.382	***	0.092	***	0.538	***	0.405	***	0.540	***
β_{ww}: ln $(\text{wood})^2$	0.017	**	0.091	***	0.003		0.042	***	0.005	
β_{AA}: ln $(\text{area})^2$	-0.051	***	0.081	***	-0.054	*	-0.051		- 0.113	***
β_{wA}: ln(wood)ln(area)	0.006		-0.086	**	-0.012		-0.054		0.045	***
Outsourcing/Costs	-0.052		-0.217	***	-0.408	***	-0.113	*	0.542	***
Subsidies/Revenues	0.515	***	0.429	***	0.270	***	0.213	**	0.593	***
Year 2005	-0.029		-0.013		0.015		0.116		-0.173	**
Year 2006	-0.045	*	-0.077	*	0.094	**	0.079		-0.263	***
Year 2007	-0.014		-0.023		0.146	***	0.145	*	-0.328	***
Year 2008	0.024		0.024		0.211	***	0.105		-0.242	***
Year 2009	0.063	**	0.097	**	0.199	***	0.128		-0.175	**
Year 2010	0.061	**	0.120	***	0.224	***	0.067		-0.223	***
Private	-0.620	***			-0.573	***	-0.580	***	-0.472	***
Mitelland	0.492	***								
Voralpen	0.115	**								
Alpen	0.221	***								
Constant	11.603	***	11.569	***	12.261	***	11.768	***	11.807	***
Adjusted R^2	0.7252		0.7875		0.7553		0.7154		0.7119	

Significant at 10% *, 5% **, 1% ***

Finally, Alpen is also a different case. In this region, the level of wood production determines the economies or diseconomies of scale only through the interaction term. Area plays the central role: economies of scale appear only as the firm reaches a certain level of total area, and it works under diseconomies of scale under it. At some point, this could lead to the same conclusion as before that only one firm is theoretically more efficient than several.

An interpretation of these results in the Alpen region could be that firms require a higher level of capital to work properly, maybe because of the rugged areas requiring specialized engines, but that these machines can be then utilized over large areas, which could support the fact that firms should increase in size to decrease average costs. More generally, another interpretation would be that administrative (or any other) costs are high but do not depend on the size of the area under management. This last observation is at least supported by the very small firms that are not efficiently managed from an economic point of view because of their size and the small financial impact it would have to act as larger firms do.

If any conclusion can be drawn from these results, beside the evident heterogeneity across and within regions because of the very different circumstances firms face, it might be argued that increasing general size of Swiss firms in the forest industry could decrease costs, surely at different degrees between regions as firms faces different environments and with no doubt for those small firms not considered in the sample.

Table 4 shows economies of scale calculated at different percentiles of the distribution of both the logarithm of wood production and total area. These economies of scale are therefore not computed for specific firms but represent a "standard" firm at each respective percentile.

Table 4: Percentile of economies of scale (ES)

Percentile	Switzerland	Jura	Mittelland	Voralpen	Alpen
10	0.802	1.136	0.766	0.669	0.808
25	0.806	1.006	0.791	0.687	0.876
50	0.840	0.903	0.835	0.718	0.934
75	0.879	0.815	0.902	0.773	1.011
90	0.914	0.761	0.978	0.834	1.077

Non-outputs coefficients

Other coefficients, not directly related to outputs, are in this short paper less crucial, even though some words can still be said on some of them.

First of all, the year dummies, which help find structural changes over time such as technological progress. 2004 was used as the basis. In this sample, no conclusion can really be made about them, beside that there is statistically no trend over the period 2004-2010. However, what is interesting to see are the differences between the regressions. For example, in the Alpen, it seems that 2004 was a special year for some reasons and was a particularly costly one.

Nevertheless, there are also some general observations arising from table 3 which are very similar across regions. Indeed, most of them turn out to agree with common sense. For example, private owners tend to decrease the total costs, everything else held constant, increasing cost efficiency. Note that Jura has omitted variables for private owners because all firms considered in this region are public ones.

Another finding concerns the impact of the percentage of subsidies over revenues, which is significantly positive for all regressions. This does not mean that subsidies increase costs, as no causal relationship is made here, but surely simply that subsidies go to those who incur the relative highest total costs. These are findings that were totally expected.

Finally, outsourcing seems to decrease costs in almost all regions. This observation might come from the fact that when some specific work has to be done, it is better to outsource it to another specialized firm than to invest heavily in any machinery needed without being able to amortize it properly. Another interpretation are that outsourced work goes to firms that are more cost efficient and thus lower the total costs for the firm outsourcing its work. The exception is the Alpen region, where outsourcing considerably increases costs. However, as for the subsidies, it does not mean that outsourcing directly increases costs since no causality is assumed. It could for example come from the fact that outsourcing is required in the Alpen when highly rugged areas need maintenance. Very specialized and costly machines are required, but outsourcing this work is still cheaper than doing it on its own. Such results are therefore to be taken with caution.

Conclusions

The costs of 1905 forestry firms in Switzerland were analyzed based on the Swiss Forestry Statistics. The translog cost function was used as a basis for the regression model, using only two outputs, aggregated wood production and total area. The lack of valid data concerning the inputs prices has made impossible to insert them in the model.

The main contribution of this short paper is to use the Swiss Forestry Statistics representing a very large sample of the Swiss forest industry, with data available and used for 1905 firms in an unbalanced panel data from 2004 to 2010. The results show the very different structures between the four regions in Switzerland. This emphasizes the fact that different regions deserve different policies, so that they are as suitable as possible to the needs and reality of each Swiss forestry firm, or at least that policy makers should be aware of and consider it in practical applications. Another important conclusion, with due care devoted to this study, is that increasing sizes of forestry firms would generally be profitable, and might then, at the long run, lower the dependency of this industry to subsidies.

As a matter of fact, it is clear that the data are very useful and that it is a very good basis for any analysis on this field. Even though the Statistics was available for a longer period, only 7 years were used. This comes from the fact that the methodology of the Statistics has changed just before 2004, which makes it difficult, if not impossible, to create a longer time-series. This task is let to possible further studies.

The main drawback of this article is surely the lack of input prices which can potentially distort results in one way or another. For this reason, among many others, the results and conclusions are to be taken with caution and are not meant to be anything else than partial, but hopefully insightful.

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10. Note on the TBN/REP data and the typology of forestry firms

Technical appendix to the report:

Analysis of the production efficiency of the Swiss forestry firms with regard to the forest functions

Submitted to the
Federal Office for the Environment FOEN

August 2012

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Introduction

This note has been prepared in response to the request of FOEN' s officials Mr. A. Kammerhofer and Mr. M. Kläy during the meeting on June 27th at the FOEN (Forest division) in Ittigen/Bern.

Given the importance of heterogeneity among the Swiss forestry firms, the FOEN and Swiss Statistics specifically mandated an exploratory typological study to the German FVA (Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg)[1]. According to the authors, the purpose of the study was to potentially enhance the meaningfulness of the test firms network (TBN). At the forefront the study should contribute to the optimization of the data collection and its regional coverage (forestry zones). The FVA has used several statistical techniques to the data from TBN, including principal component analysis (PCA), cluster analysis and discrimination analysis. In particular, cluster analysis would be able to identify classes of firms with relatively uniform characteristics.

After a brief review of the TBN data, we present a critical review of the FVA's methodology and their preliminary results. We will discuss the important factors that should be considered in a classification methodology in this context. We also propose an alternative classification approach to identify typologies based on structural differences as opposed to a purely statistical approach. Before turning to these issues, we present a brief description of a typological analysis and its potential objectives in the context of the Swiss forestry firms.

The Swiss forestry firms operate in strongly varied environments with different complexities in production and organization. Many of these differences result from structural differences that are beyond the usual characteristics such as size and quantity of production. This heterogeneity is especially important if we consider the multi-functional nature of forest services.

The Swiss forest industry suffers from financial problems that are reflected in an increasing deficit over the last two decades. The subsidized industry has raised public concerns calling for policy measures to contain the costs while maintaining the continuity of public services provided by these firms.

Effective policy measures are often far from one-for-all formulas. In order to formulate targeted policy measures it is crucial to understand the structural differences among forestry companies. If the industry is characterized by an important structural heterogeneity, an attractive solution is to classify the firms into uniform categories, hence a typological study. In general, targeted policy measures require a tractable but realistic classification of forestry firms into a number of relatively uniform typologies. The firms within a given typology are presumably comparable and hence can be subject to a similar policy or regulation. Moreover, such classifications facilitate the assessment of performance by benchmarking.

Most classification methods draw upon data mining approaches aimed at discovering the information embedded in a large number of variables. In these cases, there is usually no a-priori attached importance to one or the other variable. This is in contrast with the production context in

[1] Nagel, Ph., Hercher, W. & Hartebrodt, Ch., Typologisierung des Forst-Testbetriebsnetzes der Schweiz, Abschlussbericht 31.07.2012.

which the technology is relatively known to the analyst. In this case, there is enough ground to discriminate between the available variables depending on the objectives of the classification.

Therefore, it is important to note that the definition of typologies is closely related to the objectives of the researcher. For instance, if the policy makers are interested in differences in costs, the typological analysis needs to account for important cost drivers. If the interest is in benchmarking the firms' performance then one should exclude the variables that are under the firm's control (endogenous). It is also important to note that only part of structural heterogeneities is correlated with the observed variables. For instance, we can expect to have a more uniform grouping if we consider separate the firms by their region (e.g. the five forest regions in Switzerland). Yet, there might be important differences within the firms operating in the same region. On the other hand, there might be comparable firms in two different regions.

In cases where the structural differences are not included in the data or, are not readily observed, we can use econometric models with parameter heterogeneity. Here again, it is important to be aware of the purpose of the classification. Depending on that purpose, we can specify an econometric model to identify classes based on unobservable difference in model parameters. For instance, if the interest is on costs, then an econometric cost function with firm-specific marginal costs can be used to identify a number of typologies. These typologies will reflect differences in production techniques and costs.

The rest of this note is organized as follows. First, we present a brief description of the TBN data available for the present project on the efficiency of Swiss forestry firms. Then we elaborate on the issue of heterogeneity and typologies. In the following section, we present a review of the FVA study, before discussing the heterogeneity observed in the data based on our preliminary analyses. We also present our reflections about alternative typological approaches. Finally we conclude the note with a summary.

Data

The data base (extracted by the Swiss forest owners association (WVS), and made available by the Swiss federal statistical office FSO) contains 229 different firms over a 4-year period (2007 to 2010) initially including 88 variables. Most of these variables are divided into the four forest functions (production (WW), protection (SW), leisure (EW), nature and landscape (N&L)). The annual data consists of 200 firms per year (excepting 2008 that includes 202 firms). It is important to note that the firms are not identical across the four years. For 175 firms data is available for the entire 4-year period (balanced panel). For 19 firms data is available for one single year only, 22 firms are present over 2 years, and 13 firms appear during 3 years. The following table lists the number of firms in different years and by four forestry regions[2].

[2] The firms located in the canton Ticino, South of the Alps, are integrated in the Alps region.

Table: Number of firms with available data in TBN

Year		2007	2008	2009	2010
Total firms	229	200	202	200	200
1 year	19	6	1	2	10
2 years	22	11	14	11	8
3 years	13	8	12	12	7
4 years	175	175	175	175	175
Alpen	196	47	49	49	51
Jura	217	54	55	55	53
Mittelland	252	62	63	63	64
Voralpen	137	37	35	33	32

The initial TBN sample shows some important discrepancies in data. Focusing on main variables such as costs and a number of variables such as roads and areas that should not show a substantial change over the four years we have found a number of cases with suspicious values. Moreover, we have identified a number of observations in which the recorded numbers of input factors (employees, vehicle hours and 3rd party costs) are not consistent. If we exclude these cases from the data, we reach smaller samples. The number of remaining observations depends on the included variables. For instance if we focus on a balanced panel – i.e. in which the same firms appear over the entire observation period - with at least two non-zero inputs the sample will include 149 firms (596 observations). On the other hand, if we consider a cost function with unbalanced panel data but exclude the cases with suspicious values for roads and areas, the final sample will include 195 firms (655 observations). At this stage, we have decided to focus on the latter sample that uses a larger part of the initial data. However, in our analysis of technical efficiency where the comparison over time might require a balanced panel, we will use the former sample of 149 firms.

Our assessment of the data is rather positive: In fact, we contend that the quality of the TBN data is sufficient for a valid analysis of costs and efficiency. This expectation has been confirmed by our preliminary analyses in which we compared the results across several model specifications with and without suspicious values. In general, the number of suspicious data shows a substantial decrease over time, suggesting an amelioration of the reporting and collection processes[3].

Structural heterogeneity and uniform typologies

The Swiss forestry firms operate in strongly varied environments with respect to topography, altitude, vegetation, climate, access and infrastructure. Given the multi-functional nature of forest services these heterogeneities can take additional various forms. Many of these differences could be labeled as structural heterogeneity. By structural heterogeneity, we mean the differences in production complexities namely, leading to the differences in marginal costs of production. Even

[3] Additional information on the collection of TBN data should be gathered and a better understanding of the classifications underlying the analytical accounting procedures used in the TBN data is necessary. In particular, it is important to identify one or several relevant measures of the forestry's public services namely, the three non-timber outputs: protection, leisure and nature/landscape functions.

though all the firms might eventually use a similar technology, they face different levels of complexity of production. In a broad sense these differences are related to technological, environmental and organizational variations across firms.

In the context of cost/production models, many of these differences can be considered structural, if they cannot be accounted for by similar parameters in those models. This is particularly important when the model abstraction does not allow a full consideration of differences in input/output factors across various companies, namely because of data restrictions. In fact models generally require a tractable number of input/output factors aggregated across several groups. For instance, the timber output might be classified in a few dozen types of wood with potentially various costs of production. Aggregating all these types into a small number of categories forces the omitted variations into model parameters across firms. Obviously, the extent of heterogeneity depends on the adopted model. Overall it can be expected that, the simpler is the model, the more important is the entailed structural heterogeneity.

If we assume that the structural heterogeneity can be entirely detected with the available data, i.e. observed variables, we can use a multivariate statistical analysis such as cluster analysis to identify a number of relatively uniform clusters. The obtained clusters can be considered as representative and meaningful groups provided that adequate variables are considered in the analysis. It is important that the adopted variables represent differences in the production process and complexity. The cluster approach has been used by the FVA. A brief review of that study will be presented in the next section.

The challenging difficulty lies on the structural differences that are not included in the data or, are not readily observed. To the extent that these differences are related to marginal costs/outputs, econometric analysis can help to identify groups of relatively uniform characteristics. As opposed to a purely statistical approach such as cluster analysis, an econometric approach is based on an underlying cost or production model with specified inputs and outputs. The link of identified classes to an economic model allows a more useful interpretation of the identified classes based on informed assumptions. A purely statistical approach attaches the same importance to all included variables. The identification procedure is merely based on the correlation patterns across different variables. In contrast, an econometric approach is based on an economic model that attaches an unequal importance to the variables included in the model with regards to their contribution to costs (or production if we use a production function).

Typologies based on the FVA study

The FVA study applies several statistical techniques on a number of variables extracted from the TBN data. These techniques include principal component analysis (PCA), hierarchical cluster analysis (HCA) and linear discriminant analysis (LDA). The choice of the 19 key variables (from the 66 variables obtained for the years 2008 to 2010) is based on the values of the correlation coefficient and the experiences on similar analysis of the TBN Baden-Württemberg.

PCA and the related Factor Analysis are similar in that they both use the data in an efficient manner: small set of components or factors based on a large number of variables without losing much information. In contrast with the PCA that analyzes the observed patterns, the FA method looks for unobserved categories (factors) that can be used in a classification approach. The HCA method can also be used for such classification purposes; however it is not clear why this particular approach of clustering is chosen[4].

> The correlation matrices are not reported and the precise reasons for the selection of the 19 variables are not explained. However, in only one case where the reason is explicitly reported, a high Pearson correlation is mentioned as a reason for deleting cost of the personal in non-forest operations (Nicht WBW-Personalkosten) and surface covered by cable cranes (Seilkranfläche). The first variable is highly correlated with non forest total costs, and the second with productive non economic forest surface (WF-Prod_NichtWirtschaft). The exclusion of these two variables reduces the number of variables retained from 21 (number of variables retained for the first round of the statistical analysis) to 19 (second round). The exclusion of the two variables after the first round is justified because the discriminant analysis showed multicolliniarity for a number of the initial variables. The data was again inspected and corrected for false and missing values as well as for outliers before proceeding to the second round. The number of firms included in the second round analysis was reduced from 230 to 208. The results of the second round are then reported and discussed in some details.

An important question is that whether the components and/or the clustering approach are sensitive to the 40+ excluded variables (considering the initial set of 66 variables). We are not convinced why so many variables need to be excluded, especially considering the fact that the PCA method is used to summarize the information in 4 or 5 components. In the second (first) round, five (six) components were selected such that at least 75% of the variations in the 19 (21) variables can be explained. The authors adopted a model with 5 components and 76% explanatory power.

It is important to note that PCA is a multivariate analysis that does not distinguish between the included variables. That is, when we say 76% of the variation can be explained by 5 components, this explanatory power is referred to the variation of all the 19 variables included in the model. We wonder if such an explanation has a meaningful economic representation, because the variations of the included variables are treated with the same weight. For instance, from an economic point of view a main variable such as total costs should not be treated with the same information value as the length of access roads or state contributions.

In principle the five factors identified in the PCA could be used to group the firms. The FVA does not however report these classes. In our reading the study favors the HCA technique for the definition of clusters. Unfortunately, it is not clear which variables are included in the HCA model. According to the author the clusters analysis is based on the previously calculated factor (component) values. Our understanding is that they must have used at most the 19 variables retained for the second round or a number of (loaded) variables which have received high weights in the PCA.

The FVA study describes the obtained clusters, i.e. six hierarchical clusters with two main groups A (115 firms) and B (93 firms). The characterization of these clusters indicates that cluster B consist

[4] The authors cite in favor of the hierarchical approach that it does not require to fix beforehand the number of clusters and that several solutions could emerge from the calculation. It is best used, according to the literature cited, for a number of cases inferior to 250. The Ward method used of hierarchical clustering leads to approximately the same number of firms per cluster. It is however sensitive to outliers (which have been eliminated) and does not recognize small and "lengthy" groups.

exclusively of firms operating in Jura and Mittelland ("plateau Suisse"), while the other (cluster A) corresponds mainly but not exclusively to the Alps and Pre-Alps regions. Given that the regional indicators were not included in the key-variables, the HCA clusters show clearly that an important part of the information is embedded in the regional dummies. It also brings about an important question: Why are these indicators not included in the analysis in the first place? We are aware of the difficulties in including categorical variables in distance-based methods such as HCA. However, if the results indicate that the regions are important, there is certainly room for the revision of the model and including region indicators in the analysis.

To summarize our readings of the FVA results, we would like to highlight that the study uses statistical methods with little attention to the economic interpretations and policy objectives. We are not convinced of the economic representation of the resulting typologies. A useful classification in the context of Swiss forestry firms should be guided by two important facts that are unfortunately neglected in the FVA typologies:

- The forestry firms use a technology that is more or less similar at least for groups of firms. This implies that the input and output variables as well as costs are restricted by more or less similar technological constraints that need to be considered in any typological analysis.
- Policy objectives in the context of Swiss forests imply that the costs and outputs have a crucial importance relative to other variables. Therefore we should not deal with them the same way as with other variables. In particular, we contend that the variables should be assessed in relation with their cost impacts rather than from a purely statistical value.

Evidence of structural heterogeneity

The results of our analysis of efficiency as well as those of cost analysis indicate that the Swiss forestry firms are strongly heterogeneous. For instance the excessively low estimates of technical efficiency (reaching 50 or 60 percent on average) over the whole sample indicate that part of these apparent inefficiencies might be related to the omitted variables related to environment and other external factors beyond the firm's control. Our preliminary analysis of cost efficiency also point to implausibly low efficiency scores (averaging about 60 to 70 percent). It is important to note that such results imply that a typical firm can decrease their costs or inputs by 40 percent without any disturbance to outputs in order to reach the efficiency of the best performance observed in its peers.

We contend that these estimates are an overstatement of inefficiency. In fact, our separate analyses on slightly more uniform groups of firms suggest that part of apparent differences in efficiency can be explained by observed characteristic as well as unobserved variations: For instance if we analyze the cost efficiency of a subgroup of firms that produce a similar combination of outputs the efficiency scores will increase by about 10 percentage points.

In an econometric analysis using a multi-output cost function with several model specifications, we observed that the various outputs have different impacts on costs. We used a Box-Cox functional form to accommodate zero outputs.[5] In our preliminary analysis we distinguished the timber produced in association with the public-service functions from the wood production for purely

[5] Box-Cox transformation is a power transformation defined by $y^{(\lambda)}=(y^{\lambda}-1)/\lambda$, which encloses the logarithmic function as a limiting special case. This transformation can deal with zero values (when taking logs) while preserving the ranks of the data and stabilizing the variance. The transformed data will be closer to a normal distribution, hence more amenable to an ordinary regression analysis.

financial objectives. We therefore considered the timber output in 4 categories with 2 types of wood (firewood/industrial/etc. and logs) produced in regards to 2 functions (production function *vs* public-service function). Our working hypothesis was that the wood harvested related to public-service is perhaps less accessible and more costly to produce than the timber produced for making revenues. However, the results was against our expectations, indicating that the coefficient of timber output does not vary significantly across different functions, but varies considerably across different timber types (logs and other types). This raises two important questions about the analytical accounting procedure used in TBN which associates any cubic meter of timber output to a distinct functional category (production, protection, leisure and nature/landscape): How accurate is the separation of harvest by function? And considering the practical limitation of such separations, how helpful could they be in analyzing the cost and performance of forestry firms?

On the other hand, the cost model using a more refined output grouping suggests the cost impacts could be meaningfully separated into seven groups: timber production in 3 groups (logs, firewood and industrial/etc.) and public-service output in 4 groups (protection, leisure, nature/landscape and roads). Based on this classification, we have explored several model specifications with a number of additional variables. The results (to be reported in the final report) indicate that given the available number of observations, grouping of the outputs with more categories always lead to insignificant coefficients in one or another category and/or implausible cost effects. Therefore, given the sample size extracted from the TBN data, we believe that refining the model would not be helpful at this stage.

Finally, our cost analysis using a quantile regression approach indicates that the marginal costs of various outputs could vary substantially from one quantile to another[6]. An important difference has been observed in relation with the protection function as well as services related to roads included in the forest area. This implies that different firms might have completely different complexities that could remain unobserved for the analyst. It is important to note that marginal costs depend directly on the complexity of services which in turn varies with a variety of factors that might be among un-observables. It is also important to consider that in many cases, even if the complexity factors are observed, the assessment of their contribution in a single measure of complexity is not easy.

It is therefore important to classify the firms based on such complexities. To the extent that the structural complexity influences costs, a cost analysis can be used to classify the firms into relatively homogeneous groups.

Alternative approaches for defining typologies

Focusing on structural heterogeneity, or in other words, on the complexity of production and the resulting effect on costs, we can identify a number of variables that can be used for defining typologies. It is useful to classify these variables into two groups: observables and non-observables. The latter category includes all the complexity factors that are faced by the firm's management and employees but typically not observed by the analyst. Theoretically, these factors can be measured by expert reviews and field investigations. However, in practice such reviews are

[6] Quantile regression is a regression analysis that uses conditional quantiles (for instance, median) instead of conditional means (as in the least square method). Applying regressions at different quantiles produces different estimates at various quantiles of the data, thus allowing heterogeneity in parameters depending on the position of the point of interest in the data. For instance, quantile regression gives an estimate of the cost function for the firm at the 1st quartile, and another estimate for the median firm.

too costly. In this section, we first present our contention about the observables and then proceed to the issue of unobservable factors.

Typologies based on observable factors

In order to have a meaningful classification we need a statistical technique but also a procedure with which the relevant factors are adopted and/or constructed. Regarding the statistical technique, a suitable method is the so-called cluster analysis. In this approach the typologies (clusters) are identified so as to maximize the n-dimensional distance between groups while minimizing the distances within each group. With respect to the adoption of the relevant variables, we need some insight about the production process. The typology variables, i.e. the factors underlying the definition of typologies, should reflect the environmental complexity of the production.

Regarding the firms' first function, that is production of timber, the complexity of the production operations depends on a variety of factors related to the type of trees and the wood produced, but also on the forest's topography and access to the trees. With respect to public services, again the topography plays an important role. Especially the complexity of protective functions and road maintenance strongly depends on the topography of the service area. For instance, the median slope of the forest area can be considered as a measure of complexity, as higher slopes imply greater costs. The difference is not necessarily proportional. Forests that have steep slopes (e.g. higher than 1) might require specific equipment hence more costly.

There exist a number of observable factors that can indicate the degree of complexity of the function of a forestry firm. Other variables may characterize the production function, particularly the main production factor which is the forest itself.

A selection of relevant exogenous (largely invariant) variables used for defining typologies (typology variables) can be listed as follows:

1. Topography variables (median slope, share of steep areas, …)
2. Environmental factors (altitude, presence of surface waters, …)
3. Climatic factors (average temperature and precipitation)
4. Type and age of trees
5. Functional characteristics of the forest (share of areas corresponding to protection, leisure, nature/landscape and timber production)
6. Access variables (road density, type of roads, share of forest area without mechanized access, etc.)

In addition to the variables that characterize the forest and its environmental complexity, the type of the forest firm is also determined by organizational and institutional factors. These factors include the firm's size, the ownership, the type of governance and administration, the degree of intervention and subsidization by public authorities and the level of outsourcing and delegation to third parties. It is important to note that these factors are influenced by transaction costs, hence by the complexity of the production environment. With a few possible exceptions, such organizational factors are not exogenous. Rather, they are controlled or influenced by the firm's business strategy or government's policy.

In this case, the organizational factors should not be included in the typology variables, because those factors are not strictly imposed on the firm or can be changed by a regulator. Technically, in order to compare the performance of the firm across different organization types, the typologies need to be defined independently of those types. In other words, each typology needs to have different organization types. For instance to assess if private do better than public firms, we need to have both public and private types in a given typology.

It is worth noting that whether or not a variable is under the firm's control brings the time dimension into the equation. In many cases, the factors that cannot be varied in the short-run could be controlled in the long run. It is therefore important to consider the purpose and the time-span of the analysis. For instance, one could argue that the organization types are exogenous and cannot be varied over reasonable regulation periods. In this case, the firms operating in one type (for instance private firms) should not be penalized in favor of another type (say public firms).

Other exceptions are the factors imposed by historical and political characteristics. For instance, one can argue that the size of a forestry firm is dictated by the size of the corresponding community and cannot be changed in the intermediate term. In this case, one might favor different typologies for large and small firms.

Based on the above discussion we propose a number of organizational factors not for the definition of the typologies, but to be used in a secondary analysis to assess their impact on performance. A selective list will include:

- Ownership type
- Share of government contribution in the firm's revenues
- Share of timber production (in terms of costs or revenues) conducted via third-party contracting
- Share of third-party services provided by the firm (in terms of costs or revenues)
- Share of administration costs including expenditures for planning, marketing and training
- Firm's size (in terms of timber production or the forest service area)

Among the variables listed above, the firm's size is the only variable that can be considered in the definition of the typologies as well. An argument in favor of including a size variable in defining typologies is the fact that different scales of production might entail different levels of complexities that cannot be handled with simple measures of output in a cost/production function. This might be reflected by different equipment and harvest technologies. Assuming that size is an exogenous restricted variable in the Swiss context, a number of size categories can be used to define the relevant typologies. In particular, a separate typology can be considered for small forests that are dependent on small communities.

Finally, it should be noted that accounting for size differences is straight forward in econometric models as well as non-parametric models such as DEA. Therefore, it is not necessary to distinguish different sizes in separate typologies.

Typologies based on un-observable complexity

In addition to observable factors there are certain characteristics that cannot be observed and/or captured by simple measures of complexity. An econometric analysis of costs using models with heterogeneity in parameters can guide the classification of the relevant typologies. An example is the quantile regression approach that can be used to estimate the technology/cost parameters at different quantiles. If we consider a cost function, different quantile classes can be interpreted as a representation of different levels of complexity. It is important to note that these cost models do include a number of observable factors in particular the quantity of different outputs and other exogenous characteristics. Therefore, the definition of typologies will be based on the possible distinction of marginal impacts on costs. An advantage of this approach is in its link to the economic model thus providing a better understanding of the underlying assumptions.

Our preliminary quantile analysis indicates a substantial heterogeneity in the model parameters suggesting a strong variation in marginal costs hence complexity. Quantile regression or similar statistical models (such as latent class or finite mixture models) can be used to identify relatively homogeneous groups of forestry firms that are not only based on observable differences, but also on differences in unobserved complexity.

Conclusion

The Swiss forestry firms are characterized by a strong heterogeneity resulting in a complex industry with different shortcomings, needs and potentials. Effective policy measures should account for these differences. Moreover, it is difficult to assess any firm's performance by usual benchmarking methods that compare the firms in an indiscriminate manner.

A typological analysis (or clustering) could be useful for guiding the policy makers to attain more effective and targeted measures to improve the financial situation of the forest industry. As an ancillary benefit, distinctive typologies can be used to improve benchmarking models that can be used in monitoring the firms' performance and possibly incentive regulation methods.

In this context, it is crucial that the typological analysis is based on a sound methodology guided by the policy objectives of interest. Here, the economics of production and the costs should be the center-point of the analysis. Therefore, it is important that a cost model is used in defining the typologies. The focus should be on structural heterogeneity with respect to costs, in other words complexity of production (and provision of public services). Any clustering approach that neglects costs and technology could be counter-productive in that the obtained typologies might deviate from the economic reality, hence misleading policies in penalizing some firms and favoring others in an excessive way.

In particular, a purely statistical approach is based an uninformed methodology that attaches the same importance to all characteristics and does not consider the importance of costs and technological constraints. Such a method is at best unhelpful, but at worst could give a misleading picture of differences among forestry firms.

It is also important to consider that the structural heterogeneity (complexity) depends on the adopted model (here, cost model). A parsimonious model results in higher levels of heterogeneity whereas a refined model with a large number of parameters would entail lower heterogeneity. Therefore, the typologies and their number can vary depending on the variables included in the model specification. Given the limitation of econometric models with respect to the number of observations (number of firms in the sample), a tractable model (here, the cost function) will include a limited number of output variables defined from aggregating small output categories. The omitted variables will therefore contribute in what is identified as structural heterogeneity.

There are two approaches to tackle a typological analysis in the Swiss forest industry: One is based on a multivariate analysis (such as cluster analysis) based on a selection of observed variables that could represent the production complexity in different forest areas. This complexity might be environmental but also organizational.

A more elaborate alternative is an econometric cost model with heterogeneity of parameters (such as quantile regression, latent class or random-parameter models) that can identify the typologies based on observables but also on the unobservable differences in their impacts on costs.