Package ‘semsfa’

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Description Semiparametric Estimation of Stochastic Frontier Models following a two step procedure: in the first step semiparametric or nonparametric regression techniques are used to relax parametric restrictions of the functional form representing technology and in the second step variance parameters are obtained by pseudolikelihood estimators or by method of moments.
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Description
Semiparametric Estimation of Stochastic Frontier Models following the two step procedure proposed by Fan et al (1996) and further developed by Vidoli and Ferrara (2015) and Ferrara and Vidoli (2017). In the first step semiparametric or nonparametric regression techniques are used to relax parametric restrictions regards the functional form of the frontier and in the second step variance parameters are obtained by pseudolikelihood or method of moments estimators. Monotonicity restrictions can be imposed by means of P-splines.

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References

Description
This function calculates and returns efficiency estimates from semiparametric stochastic frontier models estimated with semsfa().

Usage
efficiencies.semsfa(semobj, log.output = TRUE, ...)

Arguments

semobj a stochastic frontier model object returned by `semsfa()`
log.output logical. Is the dependent variable logged?
... further arguments to the summary method are currently ignored

Details

The estimation of the individual efficiency score for a particular point \((x, y)\) on a production frontier might be obtained from the Jondrow et al. (1982) procedure. Defining:

\[
\sigma^2 = \sigma_u^2 + \sigma_v^2, u_*(x) = -\sigma_u^2 \epsilon / \sigma^2, \sigma_*^2 = \sigma_u^2 \sigma_v^2 / \sigma^2
\]

it can be shown that:

\[
u \mid \epsilon \sim N(\mu_*(x), \sigma_*^2(x))\]

We can use this distribution to obtain point predictions of \(u\) through the mean of the conditional distribution:

\[
E(u \mid \epsilon) = \mu_* + \sigma_* f(-\mu_*/\sigma_*)/(1 - F(\mu_*/\sigma_*))
\]

where \(f\) and \(F\) represent the standard Normal density and cumulative distribution function, respectively; alternative formulas for cost frontier models are easy to get (please see Kumbhakar and Lovell, 2000).

If the response variable is measured in logs, a point estimate of the efficiency is then provided by \(\exp(-u) \in (0, 1)\); otherwise, \((fitt - u) / fitt\) where \(fitt\) is the estimated output evaluated at the frontier, given the inputs.

Value

An object of class `semsfa` containing the following additional results:

\(u\) the prediction of the individual efficiency score
\(efficiencies\) point estimate of the efficiency

Author(s)

Giancarlo Ferrara and Francesco Vidoli

References


See Also

`semsfa`, `summary.semsfa`, `plot.semsfa`. 
Examples

```r
set.seed(0)
n<-200

#generate data
x<- runif(n, 1, 2)
fy<- 2+30*x-5*x^2
v<- rnorm(n, 0, 1)
u<- abs(rnorm(n,0,2.5))
#production frontier
y <- fy + v - u
dati<-data.frame(y,x)

#first-step: gam, second-step: fan (default)
o<-semsfa(y~s(x),dati,sem.method="gam")

#calculate efficiencies
a<-efficiencies.semsfa(o)
```

**fan**

*Pseudolikelihood estimator of the λ parameter*

**Description**

Pseudolikelihood estimator of the λ parameter

**Usage**

```r
fan(lambda_fan, resp, Ey, ineffD)
```

**Arguments**

- `lambda_fan` (the λ = σ_u/σ_v parameter to be estimated)
- `resp` (the single response variable Y observed)
- `Ey` (the conditional expectation estimate obtained in the first step of the algorithm)
- `ineffD` (logical: TRUE for estimating a production function, FALSE for estimating a cost function; this is done for usage compatibility with frontier package)

**Value**

Estimated λ parameter

**Note**

Internal usage only
Author(s)
Giancarlo Ferrara and Francesco Vidoli

References

Description
This function plots the semiparametric/nonparametric intermediate model object estimated in the first step of the algorithm and, if efficiencies.semsfa() is executed, individual point estimate of the efficiency.

Usage
## S3 method for class 'semsfa'
plot(x, g.type, mod, ...)

Arguments
- `x`: a semsfa object as returned from semsfa() or efficiencies.semsfa()
- `g.type`: a character string indicating the type of plot. Possible values are: "reg" to plot the semiparametric/nonparametric model object estimated in the first step from semsfa(), "eff" to draw point estimate of the efficiency obtained from efficiencies.semsfa()
- `mod`: a character string indicating the plot style for g.type="eff": "hist" for histogram and "dens" for density plot
- `...`: further arguments passed to plot.default.

Value
The function simply generates plots.

Author(s)
Giancarlo Ferrara and Francesco Vidoli

See Also
semsfa, efficiencies.semsfa.
Examples

```r
set.seed(0)
n<-200

#generate data
x<- runif(n, 1, 2)
y<- 2+30*x-5*x^2
v<- rnorm(n, 0, 1)
u<- abs(rnorm(n,0,2.5))
#production frontier
y <- fy + v - u
dati<-data.frame(y,x)

#first-step: gam, second-step: fan (default)
o<-semsfa(y~s(x),dati,sem.method="gam")
#the following plot will be like that generated by plot.gam
plot(o,g.type="reg")

#adding a covariate
z<- runif(n, 1, 2)
dati$z<-z

dati$z<-z

#first-step: kernel, second-step: fan (default)
o<-semsfa(y~x+z,dati,sem.method="kernel")
## Not run: plot(o,g.type="reg")

#calculate efficiencies ...
a<-efficiencies.semsfa(o)
plot(a,g.type="eff",mod="dens")

#adding further parameters as for plot.default: col, main, xlim, ...
plot(a,g.type="eff",mod="dens",col=2,main="Density Efficiency",xlim=c(0,1),xlab="Efficiency")
```

**semsfa**

Semiparametric Estimation of Stochastic Frontier Models

**Description**

Semiparametric Estimation of Stochastic Frontier Models following the two step procedure proposed by Fan et al (1996) and further developed by Vidoli and Ferrara (2015) and Ferrara and Vidoli (2017). In the first step semiparametric or nonparametric regression techniques are used to relax parametric restrictions regards the functional form of the frontier and in the second step variance parameters are obtained by pseudolikelihood or method of moments estimators. Monotonicity restrictions can be imposed by means of P-splines.

**Usage**

```r
semsfa(formula, data = list(), sem.method = "gam", var.method = "fan", ineffDecrease=TRUE, tol = 1e-05, n.boot=0,...)
```
Arguments

- **formula**: an object of class "formula": a symbolic description of the model to be fitted. The details of model specification are given under 'Details'.
- **data**: a data frame containing the variables in the model.
- **sem.method**: a character string indicating the type of estimation method to be used in the first step for the semiparametric or nonparametric regression; possible values are "gam" (default), "gam.mono" for monotone gam, "kernel" or "loess".
- **var.method**: the type of estimation method to be used in the second step for the variance components: "fan" (default) for Fan et al. (1996) approach and "mm" for method of moments.
- **ineffDecrease**: logical: TRUE (default) for estimating a production function, FALSE for estimating a cost function; this is done for usage compatibility with frontier package.
- **tol**: numeric. Convergence tolerance for pseudolikelihood estimators of variance parameters of the composed error term.
- **n.boot**: numeric. Number of bootstrap replicates to calculate standard error for the variance components, by default bootstrap standard errors will not be calculated (n.boot=0).
- **...**: further arguments accepted by mgcv::gam, gamlss::gamlss, np::npreg or loess.

Details

Parametric stochastic production frontier models, introduced by Aigner et al. (1977) and Meeusen and van den Broeck (1977), specify output in terms of a response function and a composite error term. The composite error term consists of a two-sided error representing random effects and a one-sided term representing technical inefficiency. The production stochastic frontier model can be written, in general terms, as:

$$ y_i = f(x_i) + v_i - u_i, \quad i = 1, \ldots, n,$$

where $Y_i \in \mathbb{R}^+$ is the single output of unit $i$, $X_i \in \mathbb{R}^+_p$ is the vector of inputs, $f(\cdot)$ defines a production frontier relationship between inputs $X$ and the single output $Y$. In following common practice, we assume that $v$ and $u$ are each identically independently distributed (iid) with $v \sim N(0, \sigma_v)$ and $u$ distributed half-normally on the non-negative part of the real number line: $u \sim N^+(0, \sigma_u)$; furthermore, the probability density function of the composite disturbance can be rewritten in terms of $\lambda = \sigma_u / \sigma_v$ and $\sigma^2 = \sigma_v^2 + \sigma_u^2$ for the estimation algorithm. To overcome drawbacks due to the specification of a particular production function $f(\cdot)$ we consider the estimation of a Semiparametric Stochastic Production Frontier Models through a two step procedure originally proposed by Fan et al (1996): in the first step a semiparametric or nonparametric regression technique is used to estimate the conditional expectation, while in the second step $\lambda$ and $\sigma$ parameters are estimated by pseudolikelihood (via optimize) or by method of moments estimators (var.method argument). In the case of a cost function frontier (ineffDecrease=FALSE) the composite error term is $\epsilon = v + u$. Vidoli and Ferrara (2015) suggest a Generalized Additive Model (GAM) framework in the first step even if any semiparametric or nonparametric technique may be used (Fan et al., 1996). The available methods for the first step are:

- **sem.method="gam"** invokes gam() from mgcv;
• sem.method="gam.mono" invokes gamlss() from gamlss to impose monotonicity restrictions on inputs;
• sem.method="kernel" invokes npreg() from np;
• sem.method="loess" invokes loess() from stats.

Since in the first step different estimation procedure may be invoked from different packages, the formula argument has to be compatible with the corresponding function. The available methods for the second step are:

• var.method="fan" pseudolikelihood;
• var.method="mm" Method of Moments.

Value

semsfa() returns an object of class semsfa. An semsfa object is a list containing the following components:

formula the formula used
y the response variable used as specified in formula
data the data frame used
call the matched call
sem.method the type of semiparametric or nonparametric regression as given by sem.method ("gam", "gam.mono", "kernel", "loess")
var.method the type of error component estimator ("fan", "mm")
ineffDecrease logical, as given by ineffDecrease
reg an object of class "gam", "gamlss" (monotone gam), "np"(kernel) or "loess" depending on sem.method
reg.fitted fitted values on the "mean" frontier (semiparametric/non parametric regression)
regkewness asymmetry index calculated on residuals obtained in the first step
lambda λ estimate
sigma σ estimate
fitted fitted values on the frontier
tol convergence tolerance for pseudolikelihood estimators used in optimize
residual.df residual degree of freedom of the model
bic 'Bayesian Information Criterion' according to the formula
\[-2*\text{log-likelihood} + \log(n)*npar\]
where npar represents the number of parameters in the fitted model and n the number of observations
n.boot number of bootstrap replicates used (default n.boot=0)
boot.mat a matrix containing λ and σ values from each bootstrap replicate (if n.boot>0)
b.se boostrapped standard errors for λ and σ (if n.boot>0)
**Note**

The function `summary.semsfa` (i.e. `summary.semsfa`) can be used to obtain a summary of the results, `efficiencies.semsfa` to calculate efficiency scores and `plot` (i.e. `plot.semsfa`) to graph efficiency previsions and regression components (i.e. the first step).

You must take the natural logarithm of the response variable before fitting a stochastic frontier production or cost model.

**Author(s)**

Giancarlo Ferrara

**References**


**See Also**

`summary.semsfa`, `efficiencies.semsfa`, `plot.semsfa`.

**Examples**

```r
set.seed(0)
n<-200

x<- runif(n, 1, 2)
v<- rnorm(n, 0, 1)
u<- abs(rnorm(n,0,2.5))

#cost frontier
fy<- 2+30*x+5*x^2
y <- fy + v + u

dati<-data.frame(y,x)
#first-step: gam, second-step: fan
o<-semsfa(y~s(x),dati,sem.method="gam",ineffDecrease=FALSE)
```
#first-step: gam, second-step: mm
## not run: o<-semsfa(y~s(x),dati,sem.method="gam",ineffDecrease=FALSE,var.method="mm")
plot(x,y)
curve(2+30*x+5*x^2,add=TRUE)
points(sort(x),o$fitted[order(x)],col=3,type="l")

#production frontier
fy<- 2+30*x-5*x^2
y <- fy + v - u

dati<-data.frame(y,x)
#first-step: gam, second-step: fan
o<-semsfa(y~s(x),dati,sem.method="gam",ineffDecrease=TRUE)
plot(x,y)
curve(2+30*x-5*x^2,add=TRUE)
points(sort(x),o$fitted[order(x)],col=3,type="l")

#imposing monotonicity restrictions on inputs
set.seed(25)
n=150
x=rnorm(n,0.3)
u=abs(rnorm(n,0,1))
v=rnorm(n,0.75*((pi-2)/pi))

#production frontier
fy<-10-5*exp(-x)
y <- fy+v-u
dati<-data.frame(y,x)
#first-step: monotone gam, second-step: fan
o<-semsfa(y~pbm(x,mono="up"),sem.method = "gam.mono",dati)
plot(x,y)
curve(10-5*exp(-x),add=TRUE)
points(sort(x),o$fitted[order(x)],col=3,type="l")

---

**summary.semsfa**

*Summary for semsfa object*

**Description**

Create and print summary results of a stochastic frontier model object returned by `semsfa()` with regard to the "CONDITIONAL EXPECTATION ESTIMATE" of the first step and to the "VARIANCE COMPONENTS ESTIMATE" of the compound error.

**Usage**

## S3 method for class 'semsfa'
summary(object, ...)
Arguments

object an `semsfa` object returned by `semsfa()`

... further arguments to the `summary` method are currently ignored

Details

Please note that if bootstrap is carried out the $t$-statistic is not reliable for testing the statistical significance of $\sigma$ and $\lambda$, because these parameters are censored and cannot follow a $t$-distribution. We suggest to compare the BIC of the semiparametric estimated model with the base model.

Value

`summary.semsfa` returns the summary of an object returned by `semsfa()` with few modifications if bootstrap is carried out:

- `b.t` $t$-statistic given the bootstrapped standard errors for $\lambda$ and $\sigma$ (`b.se`)
- `b.pv` $p$-values of the $t$-statistic

Note

`summary` returns the same result if applied to an object created with `semsfa` or `efficiencies.semsfa`

Author(s)

Giancarlo Ferrara and Francesco Vidoli

See Also

- `semsfa`, `efficiencies.semsfa`

Examples

```r
#generate data
set.seed(0)
n<-200

x<- runif(n, 1, 2)
fy<- 2+30*x-5*x^2
v<- rnorm(n, 0, 1)
u<- abs(rnorm(n,0,2.5))
#production frontier
y <- fy + v - u
dati<-data.frame(y,x)

#first-step: gam, second-step: fan (default)
#without bootstrap
o<-semsfa(y~s(x),dati,sem.method="gam")
summary(o)
```
# ... with bootstrap

```r
o <- semsfa(y ~ s(x), dat, sem.method = "gam", n.boot = 100)
summary(o)
```
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