

# Package ‘irtbem2pl’

June 8, 2026

**Title** Marginalized Bayesian Item Parameter Estimation, 2pl Model IRT

**Version** 1.0.0

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**Description** Estimates item parameters of the two-parameter logistic (2PL) model in Item Response Theory (IRT) using the marginal Bayesian modal estimation via the Expectation-Maximization (EM) algorithm. The package calibrates item discrimination and difficulty parameters, yielding results comparable to software like 'BILOG-MG'.

**License** GPL (>= 2)

**URL** <https://github.com/juanluislegorretatorres/irtbem2pl>

**Depends** R (>= 3.5.0)

**Imports** IRTBEMM

**NeedsCompilation** no

**Encoding** UTF-8

**Language** en-US

**RoxygenNote** 7.3.2

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**Repository** CRAN

**Date/Publication** 2026-06-08 18:10:10 UTC

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dat01

*Dichotomous Response Dataset for IRT Calibration*

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### Description

A sample dataset containing binary examination responses used to demonstrate 2PL model parameter estimation.

### Usage

```
data(dat01)
```

### Format

A data frame with rows representing examinees and 20 columns representing items (ITEM001 to ITEM023). Responses are dichotomous where 1 indicates a correct response and 0 indicates an incorrect response.

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irt2pl

*Estimation of the 2PL Model via Marginal Bayesian Modal Estimation*

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### Description

Estimates item discrimination and difficulty parameters for the two-parameter logistic (2PL) model using an Expectation-Maximization (EM) algorithm with Bayesian priors.

### Usage

```
irt2pl(  
  Model = Model,  
  data = data,  
  data.simple = data.simple,  
  CountNum = CountNum,  
  n.class = n.class,  
  Prior = Prior,  
  Par.est0 = Par.est0,  
  Par.SE0 = Par.SE0,  
  D = D,  
  np,  
  Tol = Tol,  
  max.ECycle = max.ECycle,  
  max.MCycle = max.MCycle,  
  n.Quadpts = n.Quadpts,  
  n.decimal = n.decimal,  
  Theta.lim = Theta.lim,
```

```

Missing = Missing,
ParConstraint = ParConstraint,
BiasSE = BiasSE,
I = I,
J = J,
Time.Begin = Time.Begin
)

```

## Arguments

Model	An object specifying the IRT model configuration.
data	A data frame or matrix containing the raw response data.
data.simple	A simplified or matrix version of the response data.
CountNum	A numeric vector indicating the frequency of each response pattern.
n.class	An integer specifying the number of latent classes or groups.
Prior	A list containing the prior distributions for parameters A and B.
Par.est0	A list with the initial parameter estimates for the items.
Par.SE0	A list with the initial standard error estimates.
D	A numeric scaling constant (typically 1.7 or 1.0).
np	An integer representing the number of items or parameters.
Tol	A numeric value specifying the convergence tolerance limit.
max.ECycle	An integer indicating the maximum number of E-steps.
max.MCycle	An integer indicating the maximum number of M-steps.
n.Quadpts	An integer specifying the number of quadrature points.
n.decimal	An integer for decimal formatting in output objects.
Theta.lim	A numeric vector of length 2 defining the boundaries of theta.
Missing	A value or matrix specifying how missing data is handled.
ParConstraint	A logical value indicating if parameter constraints are applied.
BiasSE	A logical value specifying if bias-corrected standard errors are computed.
I	An integer representing the total number of examinees.
J	An integer representing the total number of items.
Time.Begin	A POSIXct timestamp marking the start of the execution.

## Value

A list containing the calibrated item parameters, information matrices, and convergence metadata.

**Description**

' Estimates item parameters of the two-parameter logistic (2PL) model using marginal Bayesian modal estimation via the Expectation-Maximization (EM) algorithm. The results are similar to those of "BILOG-MG", from the book Item Response Theory Parameter Estimation Techniques.

**Usage**

```
irtbem2pl(
  data,
  PriorA = c(0, 0.25),
  PriorB = c(0, 4),
  InitialA = 1,
  InitialB = 0,
  Tol = 0.01,
  max.ECycle = 50L,
  max.MCycle = 10L,
  n.decimal = 5L,
  n.Quadpts = 50L,
  Theta.lim = c(-4, 4),
  Missing = -9,
  ParConstraint = FALSE,
  BiasSE = FALSE,
  D = 1
)
```

**Arguments**

data	A matrix or data.frame consisting of dichotomous data (1 for correct and 0 for wrong response).
PriorA	A numeric vector with two hyperparameters: the mean and variance of the log-normal distribution for all a parameters. Defaults to c(0, 0.25).
PriorB	A numeric vector with two hyperparameters: the mean and variance of the normal distribution prior for item difficulty (b) parameters. Defaults to c(0, 4).
InitialA	A single numeric value or vector specifying initial values for the item discrimination parameters (a). Defaults to 1. It is recommended to use the point-biserial correlation from Classical Test Theory.
InitialB	A single numeric value or vector specifying initial values for the difficulty parameters (b). Defaults to 0. It is recommended to use the item difficulty index from Classical Test Theory.
Tol	A single numeric value specifying the convergence threshold for E-step cycles. Defaults to 0.01.

max.ECycle	A single integer specifying the maximum number of E-step cycles. Defaults to 50L.
max.MCycle	A single integer specifying the maximum number of M-step cycles. Defaults to 10L.
n.decimal	A single integer specifying the number of decimal places for the output results. Defaults to 5L.
n.Quadpts	A single integer specifying the number of quadrature points per dimension (must be larger than 5). Defaults to 50L.
Theta.lim	A numeric vector of length 2 defining the integration grid range for each dimension. Defaults to c(-4, 4).
Missing	A single numeric value indicating missing elements. Defaults to -9. Cannot be 0 or 1.
ParConstraint	A logical value indicating whether to restrict estimates within a reasonable range. Defaults to FALSE.
BiasSE	A logical value determining whether to estimate SEs directly from the inverted Hessian matrix. Defaults to FALSE.
D	A numeric scale constant (1 or 1.702). Defaults to 1.

### Details

The two-parameter logistic (2PL) model proposed by Birnbaum (1968) is defined as:

$$P(x = 1|\Theta, a, b) = \frac{1}{1 + \exp(-D \cdot a \cdot (\Theta - b))}$$

where  $x=1$  is the correct response,  $\Theta$  is the examinee's ability,  $a$  is the item discrimination, and  $b$  is the difficulty parameter.

### Value

A list containing the following components:

- `Est.ItemPars` A data frame with estimates of parameters  $a$  and  $b$ , along with their standard errors.
- `Est.Theta` A data frame with EAP ability estimates and their standard errors.
- `Loglikelihood` The final log-likelihood value.
- `Iteration` The number of iterations until convergence.
- `EM.Map` The parameter estimation history across iterations.
- `fits.test` Model fit statistics including  $G^2$ , AIC, BIC, and RMSEA.
- `Elapsed.time` Total execution time of the program.
- `InitialValues` The initial values used for item calibration.

### Author(s)

Juan Luis Legorreta Torres <jlegorreta2002@yahoo.com.mx>

## References

- Baker, F. B., & Kim, S.-H. (2004). *Item Response Theory: Parameter Estimation Techniques* (2nd ed.). Marcel Dekker.
- Birnbaum, A. (1968). Some latent trait models and their use in inferring an examinee's ability. In F. M. Lord & M. R. Novick (Eds.), *Statistical theories of mental test scores* (pp. 395-479). Addison-Wesley.

## Examples

```
data(dat01)

# It is recommended to use:
# InitialA = point-biserial correlation (Classical Test Theory)
# InitialB = item difficulty index (Classical Test Theory)

mod_2PL <- irtbem2pl(data = dat01, PriorA = c(0, 0.25), PriorB = c(0, 4),
                    InitialA = 1, InitialB = 0, Tol = 0.01, max.ECycle = 50L,
                    max.MCycle = 10L, n.decimal = 5L, n.Quadpts = 50L,
                    Theta.lim = c(-4, 4), Missing = -9, ParConstraint = FALSE,
                    BiasSE = FALSE, D = 1)

mod_2PL$Est.ItemPars      # show item estimates
mod_2PL$Est.Theta        # show ability estimates
```

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 irtchek2pl

*Checking user specified input variables*


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## Description

Verifies whether the input variables provided by the user are correct based on the 2PL model specifications. If acceptable, the function formats and returns them as a combined list; otherwise, it throws an error

## Usage

```
irtchek2pl(
  Model = "2PL",
  data,
  PriorA = c(0, 0.25),
  PriorB = c(0, 4),
  InitialA = 1,
  InitialB = 0,
  Tol = 0.01,
  max.ECycle = 50L,
  max.MCycle = 10L,
  n.decimal = 5L,
  n.Quadpts = 50L,
```

```

  Theta.lim = c(-4, 4),
  Missing = -9,
  ParConstraint = FALSE,
  BiasSE = FALSE,
  D = 1
)
```

### Arguments

Model	A character string declaring the type of item model (e.g., "2PL").
data	A matrix or data.frame consisting of dichotomous data (1 for correct and 0 for wrong response), with missing data coded as in Missing.
PriorA	A numeric vector or matrix specifying the log-normal prior distribution hyperparameters (mean and variance) for item discrimination. Defaults to c(0, 0.25).
PriorB	A numeric vector or matrix specifying the normal prior distribution hyperparameters (mean and variance) for item difficulty. Defaults to c(0, 4).
InitialA	A single numeric value or vector specifying initial values for item discrimination parameters. Defaults to 1.
InitialB	A single numeric value or vector specifying initial values for item difficulty parameters. Defaults to 0.
Tol	A single numeric value specifying the convergence threshold for E-step cycles. Defaults to 0.01.
max.ECycle	A single integer specifying the maximum number of E-step cycles. Defaults to 50L.
max.MCycle	A single integer specifying the maximum number of M-step cycles. Defaults to 10L.
n.decimal	A single integer specifying the number of decimal places for output formatting. Defaults to 5L.
n.Quadpts	A single integer specifying the number of quadrature points per dimension. Defaults to 50L.
Theta.lim	A numeric vector of length 2 defining the integration grid boundaries. Defaults to c(-4, 4).
Missing	A single numeric value indicating missing elements. Defaults to -9. Cannot be 0 or 1.
ParConstraint	A logical value indicating whether parameters are constrained within a reasonable range. Defaults to FALSE.
BiasSE	A logical value determining whether to estimate SEs directly from the inverted Hessian matrix. Defaults to FALSE.
D	A numeric scaling constant (1 or 1.702). Defaults to 1.

### Value

A combined list containing formatted data arrays, sample sizes, prior specifications, initial parameter values, and convergence controls.

**Author(s)**

Juan Luis Legorreta Torres <jlegorreta2002@yahoo.com.mx>

**References**

*Item Response Theory Parameter Estimation Techniques* Second Edition, Revised and Expanded  
 Frank B. Baker University of Wisconsin Madison, Wisconsin, U.S.A. Seock-Ho Kim The University  
 of Georgia Athens, Georgia, u.S.A.

**Examples**

```
data(dat01)
library(irtbem2pl)
Checking_2PL<-irtchek2pl(Model = "2PL", dat01, D = 1)
```

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 LikelihoodInfo2pl

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*Compute Likelihood Information for the 2PL IRT Model*


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**Description**

' Calculates the log-likelihood, deviance, and expected frequencies (f, fz, rz) required for the E-step of the Expectation-Maximization (EM) algorithm under a two-parameter logistic (2PL) model.

**Usage**

```
LikelihoodInfo2pl(
  data.simple,
  CountNum,
  Model,
  Par.est0,
  n.Quadpts,
  node.Quadpts,
  weight.Quadpts,
  D
)
```

**Arguments**

<code>data.simple</code>	A numeric matrix representing the simplified unique response patterns.
<code>CountNum</code>	A numeric vector containing the frequencies of each unique response pattern.
<code>Model</code>	A character string declaring the type of IRT model to be evaluated (e.g., "2PL").
<code>Par.est0</code>	A list containing current item parameter estimates (A and B).
<code>n.Quadpts</code>	A single integer indicating the number of quadrature points.
<code>node.Quadpts</code>	A numeric vector containing the nodes of the quadrature grid.
<code>weight.Quadpts</code>	A numeric vector containing the weights of the quadrature grid.
<code>D</code>	A numeric scaling constant (typically 1 or 1.702).

**Value**

A list containing the following statistical components:

- LH The log-likelihood value of the model given the data.
- Deviance The model deviance statistic calculated as  $-2 * LH$ .
- f A numeric matrix of expected frequencies per quadrature point.
- fz A numeric matrix of expected correct response frequencies based on P\*.
- rz A numeric matrix of expected correct joint frequencies.

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 Prob.model

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*Compute Item Response Probabilities for Various IRT Models*


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**Description**

Calculates the probability of a correct response for a given latent trait level (Theta) under specified Item Response Theory (IRT) models.

**Usage**

```
Prob.model(X, Model, Par.est0, D = 1)
```

**Arguments**

X	A numeric value or vector representing the latent trait level (Theta) or quadrature node.
Model	A character string specifying the IRT model type. Options include "Rasch", "2PL", "3PL", "4PL", "1PLAG", or "1PLG".
Par.est0	A list containing current item parameter estimates (A, B, C, S, Beta, Alpha, Gamma, depending on the model).
D	A numeric scaling constant (typically 1 or 1.702). Defaults to 1.

**Value**

A numeric vector or matrix containing the calculated correct response probabilities, bounded between  $1e-12$  and  $(1 - 1e-12)$  for numerical stability.

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